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THE MIDDLE ORDOVICIAN OF THE OSLO REGION, NORWAY

10. Nautiloid Cephalopods

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With 21 plates and 20 figures in text

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Abstract: Forty identifiable species of nautiloid cephalopods, referable to 38 genera, are described from the Middle Ordovician Ogygiocaris and Chasmops Series of the Oslo Region, Norway. A comparison of the cephalopod faunas represented with others in the Scando-Baltic province tends to confirm previously suggested correlations of the Ogygiocaris Series with the Platyurus, Schroeteri, and at least part of the Crassicauda limestones of Sweden. Many of the same cephalopod species found in Ogygiocaris strata are also known from the Aseri, Lasnamäe, and Uhaku limestones of Estonia, and two species from the lower portion of this Series are closely similar to forms known best from the essentially contemporaneous Šàrka beds of Bohemia. Ogygiocaris Series cephalopods have little in common with presumably contemporaneous forms in North America, but the same general fauna, or regional variants of it, seems to occur in Korea, Manchuria, India, and perhaps in Australia, China, and Argentina.

The cephalopods of the Ampyx limestone, the basal substage of the Chasmops Series, are much like those of the upper part of the Ogygiocaris Series, and seem to be closely related to forms from the Crassicauda limestone of Sweden and the Uhaku limestone of Estonia. The few nautiloids now known from the upper four-fifths of the Chasmops Series, are, however, for the most part referable to, or closely related to, genera best developed in the well known boreal faunas which have a wide distribution in the Northern Hemisphere.

In the systematic portion of the report, three new generic names are proposed, *Hoeloceras* (Lambeoceratidae), *Trilacinoceras* (Lituitidae), and *Broeggeroceras* (Westonoceratidae). In addition, 21 species are named and described for the first time. Descriptions and illustrations of one Lower Ordovician species (*Holmiceras kjerulfi* (Brøgger)) and one Upper Ordovician species (*Broeggeroceras? elongatum*, n. gen. & sp.) are included for comparative purposes.

The stratigraphic distribution and morphological development of the Lituitidae indicate a close relationship to the Tarphyceratina. Lituitid cameral deposits are discussed and evidence is presented to suggest that these structures were secreted by siphuncular tissue which expanded into the camerae through foramina resorbed in the ectosiphuncle. The independent development of cameral deposits in the secondarily straight lituitids supports the interpretation of such structures as hydrostatic devices and suggests that the Lituitidae developed from a stock in which cameral tissues had disappeared or lost their function.

Introduction and acknowledgements.

The following is the tenth report in a series begun by Størmer in 1953 and designed to elucidate the stratigraphic and paleontologic features of Middle Ordovician strata in the Oslo Region, Norway. The present study, which deals with the nautiloid cephalopods, is based primarily upon specimens in collections at the Paleontological Museum in Oslo and the State Museum of Natural History in Stockholm. However, during 1956 and 1957, I had the opportunity to collect from some localities at which Middle Ordovician strata are exposed, and descriptions of many cephalopods found on these occasions are also included. Since most exposures in the Oslo Region have been visited many times by experienced paleontologists, it is not likely that many well preserved nautiloids would have escaped notice. Therefore, it seems likely that the aggregate of the collections at hand closely approximates the composition of the cephalopod faunas as a whole.

It should perhaps be mentioned that the collections which form the nucleus of this report have been assembled by many different persons during a period of more than 100 years. The information accompanying many specimens is vague or incomplete stratigraphically, and, although some can be placed in the section on the basis of lithology or associated fossils, little stratigraphic significance can be attributed to them.

Many of these poorly labelled cephalopods are described, however, and several species are erected on the basis of rather scanty material with the hope that descriptions of them will serve as a guide to further more systematic collecting.

I wish to express my appreciation to the United States Educational Foundation in Norway for generous financial aid which made it possible for me to spend a year in Scandinavia; and to Professor Leif Størmer, director of the Paleontological Institute (now part of Institute of geology) at Oslo University, for his help and many kindnesses throughout my stay in Oslo. The assistance and counsel of Dr. Gunnar Henningsmoen and Dr. Nils Spjeldnæs, both of the Paleontological Museum, Oslo, is also warmly acknowledged, as is the kindness of Mrs. Natascha Heintz, who translated parts of several Russian papers for me. Professor Erik Stensiö, Palæozoological Division, State Museum of Natural History, Stockholm, graciously made the facilities of his institution available during my visits there, and assisted in the completion of the present project by arranging loans of type material and specimens of Norwegian and Swedish nautiloids stored in Stockholm. I have also profited through an exchange of stratigraphic and paleontologic ideas with Dr. Valdar Jaanusson, Paleontological Institution, Uppsala University, and Fil. Lic. Harry Mutvei, State Museum of Natural History, Stockholm. The skill of Miss Bergljot Mauritz, Faculty Photographer at the University of Oslo, and the artistry of Miss Ingrid Lowzow is evident in the plates and text-figures, and I express my appreciation to both for the time and care their preparation required. Mr. Einar Fjellet prepared many of the polished sections. The illustrations and sections were financed by funds from Norwegian Research Council grants for joint studies of the Middle Ordovician of the Oslo Region.

THE CEPHALOPOD FAUNAS

Previous mention

As early as 1784, Hans Strøm described and illustrated a nautiloid cephalopod (of a type now referable to the Endoceratidae) from the Oslo Region, and in 1797, Christian Hammer gave descriptions (but apparently no illustrations) of several straight and coiled species from

Melbostad in the Hadeland district. Neither Strøm nor Hammer include generic or specific names or very exact information as to their collecting localities. Hammer, however, attempted to identify his specimen by comparing them with Gmelin's figures.

On his trip to Norway, Leopold von Buch (1810) collected cephalopods at several places in the Oslo Region. Lossen (1860a, 1860b) described part of von Buch's collection, referring two specimens to *Lituites arcuatus* and several others to *Lituites trapezoidalis*. *L. arcuatus* has never been illustrated, but according to Lossen (*op. cit.*) the species was based on specimens from the Toten district which were almost certainly collected from the so-called Cephalopod shale. Several years ago, Professor Trygve Strand, of Oslo University, studied the only available type of *L. aruatus* and his observations, together with a photograph of the specimen, are included in the present report. *Lituites trapezoidalis*, the types of which come from Asker, southwest of Oslo, has long been regarded as synonymous with *Discoceras antiquissimum* (Eichwald), an Upper Ordovician species.

Esmarck (1829) remarks that, on this trip to Trondheim, he observed representatives of *Orthoceratites* and *Lituites* on Helgøya, an island in Lake Mjøsa. He gives no figures of these fossils, but he does include short generalized descriptions of them and remarks as to their probable original length and size.

Kjerulf (1857) was apparently the first to publish faunal lists for the strata in the "Christiania [Oslo] Basin". From his Etage 3 (which represents a mixture of stages 3 and 4 as now recognized) he lists (p. 285): *Orthoceratites communis* Wahl., *O. imbricatum* Wahl., *O. regularis*, *O. duplex*, *O. trochlearis* His., *O. annulatus* Sow., *Lituites lituus*, and *Trocholites*. From Etage 4 he identified *O. regularis* His., *O. attenuatum dimidiatum* Murch., *O. undulatus*, *O. lineatus*, *O. gigas*, *O. distans*, *O. duplex*, *Cyrtoceras*, *Lituites cornu-arietis* Sow., and *Trocholites anguiformis* Salter. In the latter part of the same paper, Th. Dahll reports several of the same species, as well as *Cyrtoceras inaequiseptum*, from the Langesund—Skien district, southwest of Oslo. A majority of these species are Middle Ordovician forms, and Kjerulf's collections form a large part of the ones described in a later part of the present report. For the most part, however, it is not known to which specimens he applied the names listed in his 1857 paper.

In 1865, Kjerulf again noted the fossils common to the sedimentary strata of the Oslo Region, and presented lists including 18 cephalopod species, at least 12 of which are certainly Middle Ordovician. One of these, *Lituites lynnensis,* was described and illustrated for the first time in that report. It is interesting to note that in his 1865 report and on Atlas Sheet 10 of a paper published in 1879, Kjerulf mentions the occurence of *Gonioceras anceps* Hall in the upper part of Stage 4 on Nakkholmen Island. I have not been able to locate the specimen(s) upon which Kjerulf based this determination, but it may have been like the one from substage 4bβ here made the type of *Hoeloceras askeri.* However, sinces Stage 4 includes Upper Ordovician strata, it is equally possible that Kjerulf's *G. anceps* is Upper, rather than Middle Ordovician in age, although the type of that species (upon which Hall based *Gonioceras*) comes from the Watertown formation of Wilderness ("Black River") age in New York.

Brøgger (1884) mentions the occurence of cephalopods (*Lituites lituus* Montf. and "Orthoceren") in the Cephalopod shale at Mjøsa, and also records the occurrence of lituitids and orthoceracones in the Chasmops limestone and shale, and in the Encrinite limestone of the Langesund—Skien district. However, he provided no descriptions or illustrations of these forms. At about this same time, the Swedish paleontologist, Gerhard Holm, made several trips to the Oslo Region to collect fossils, and, during these trips, he assembled a large collection of cephalopods, primarily on Helgøya in Lake Mjøsa. He apparently intended to study these forms thoroughly, but as far as I can determine, he mentions (1885, p. 17) only one of them, *Endoceras gladius*, in his many papers on Scandinavian fossils. Holm's collections are now stored at the State Museum of Natural History in Stockholm, and I have been through them carefully. Several of the specimens he collected are not duplicated in the collections in Oslo, hence are described in the following report.

In his "Catalogue of Fossil Cephalopods . . ." (1888, 1891), Foord mentions conspecific Norwegian specimens in connection with his descriptions of *Orthoceras regulare* (Schlotheim), *Endoceras wahlenbergi* Foord, *E. trochleare* (Hisinger), and *Lituites lituus* Montfort. All of these are Middle Ordovician species, and are ascribed to either the Oskarshall group or Stage 4 at various localities in the Oslo Region.

In 1909, Holtedahl published an important paper on Stage 4 in the Lake Mjøsa district, in which work (p. 40—42) he lists *Orthoceras regulare* Schl., *O. centrale* His., *O. devexum* Eich., *Endoceras gladius* Holm, *Cyrtoceras priscum* Eichw., *C. oryx* Eichw., *C. digitale* Eichw., *Trocholites contractus* Schröder, *T. remelei* Schröder, *T. damesi* Schröder, *T.* aff. *macromphalus* Schröder, *Lituites lituus* Montfort, and *L. perfectus* Wahlenberg? from $4A_3$ (the Cephalopod shale); *O. scabridium* Angelin from $4B_2$ (the Coelosphaeridium beds); and *O. suave* and *O. cuneolus* Eichwald from $4B_3{}^b$ (the Cyclocrinus zone). I have not located all of Holtedahl's specimens, but several of his identifications are confirmed by a study of material from the same general horizons, and some of his determinations are revised in the present report.

Orthoceratites regularis Schlotheim is the type of *Orthoceros* Brünnich and, although it might be expected in $4a\alpha_4$, none of the specimens available to me can be referred to it with certainty. Troedsson (1931, p. 28) also notes that he was unable to verify the presence of this species in the Norwegian Ordovician. Hisinger's *Orthoceratites centralis* is based on an orthoceraconic fragment which has a central siphuncle and a transversely striated shell. It may be referable to *Orthoceros* or it may be a *Stereoplasmocerina*, like *S. lineatum*, n. sp., which occurs in stratigraphically comparable beds. However, it is not possible to place the species in any genus with certainty at the present time. Balaschov (1953a, p. 211) refers *Orthoceras devexum* Eichwald to *Palaeocycloceras* Shimizu & Obata, which, however, is regarded by Flower (1943c, p. 122) to be a junior subjective synonym of *Protocycloceras* Hyatt, an ellesmeroceratinid. As Balaschov's reference is unaccompanied by any explanatory notes and since I have not found any annulated ellesmeroceratinids in Holtedahl's or other collections from the Middle Ordovician of the Oslo Region this identification must be regarded with question. *Endoceras gladius* Holm is apparently synonymous with *Nanno belemnitiforme* Holm, which has priority.

Cyrtoceras priscum, *C. oryx*, and *C. digitale*, all of Eichwald certainly do not belong in *Cyrtoceras* as it is presently recognized, but it is not possible at the present time to revise the generic reference of their types. It might be pointed out, however, that Balaschov (1953a, p. 208) lists "*Cyrtoceras*" *priscum* Eichwald from zone F of the Estonian section, hence it is unlikely that Holtedahl's Middle Ordovician specimen is conspecific. The form which Holtedahl placed in *C. oryx* Eichwald is illustrated as figure 1 on Plate 10, but its generic and specific reference cannot be determined. There is, however, a suggestion of trochoid coiling in this specimen which, if verified by subsequent collecting, will probably necessitate the erection of a new generic category for it. I have not been able to locate any specimen labelled *C. digitale*, but it may be either the one here described as *Strandoceras strandi*, n. sp., or as *Valcouroceras? holtedahli*, n. sp.

Trocholites contractus Schröder occurs in the Cephalopod shale as, Holtedahl states, but the specimens he placed in *T. remelei* Schröder and *T.* aff. *macromphalus* Schröder, are probably the ones here referred to *T. depressus* (Eichwald). *Trocholites damesi* Schröder is more properly referred to *Discoceras*, but the name cannot be used with certainty for any of the trocholitids in collections available to me.

Both *Lituites lituus* Montfort and *L. perfectus* Wahlenberg occur in the Ogygiocaris Series, and Holtedahl's reference to them is undoubtedly correct; however, I have not discovered representatives of either species in collections from the Cephalopod shale.

Geisonoceras [= *Orthoceras*] *scabridium* (Angelin) appears to be the only cephalopod known from the Coelosphaeridium beds, and, with the addition of *Discoceras ievesense* (Balaschov), the same seems to be true of *Kionoceras* [= *Orthoceras*] *suave* (Angelin) and *Allumettoceras* [= *Orthoceras*] *cuneolum* (Eichewald), both reported by Holtedahl from the Cyclocrinus beds. The only specimen in collections at hand (P.M.O. I 1478) labelled *O. cuneolus* Eichwald, comes from Hovindsholm, presumably from the Cephalopod shale. This specimen has a central, orthochoanitic siphuncle, and is being referred to *Sactorthoceras*. However, *Allumettoceras* does occur in the Cephalopod shale, and its presence in the somewhat younger Cyclocrinus beds would therefore not be surprising.

In 1932, Troedsson prepared a thorough study of the vertically striated orthoceracones in the Swedish Orthoceras limestone, in which he also included descriptions of *Protokionoceras strandi* Troedsson, and a *Polygrammoceras*, both from some part of the Chasmops Series (4b) in the Oslo Region. Troedsson's descriptions are included in the present report, and the latter specimen is figured for the first time (Plate 2, figures 7 and 10). Troedsson also remarks (1932, introduction,

p. 1) that a specimen from the Ogyiocaris Series of the Oslo Region "... reminds one of *P.* [*Polygrammoceras*] *fasciatum* but is a true *Spyroceras* ...", and " ... a speciemen labelled *Orthoceras amplicameratum* in the Paleontological Museum of Oslo, is poorly preserved and does not show any longitudinal striation at all." I have not been able to locate either of these specimens, but it should be noted that no true *Spyroceras* is known to occur below the Lower Devonian and the specimens available to Troedsson for study may have been like those here referred either to *Gorbyoceras?* or *Ctenoceras.*

Careful systematic descriptions and an excellent stratigraphic analysis of all the Upper Ordovician cephalopods then known from the Oslo Region were published by Strand (1933). In his work are also included descriptions of *Ephippiorthoceras frognøyense* Strand, *Strandoceras* [as *Protophragmoceras*] sp., and several generically indeterminate lituitids now known to have been collected from rocks of uppermost Middle Ordovician age. Strand's descriptions of the first two of these forms are reproduced here, but the types are not illustrated.

Subsequent to Strand's work, Norwegian cephalopods have been mentioned and/or illustrated only in connection with general stratigraphic or popular discussions, or (as in Flower, 1946) in connection with revisions in generic or specific taxonomy.

It should be added that, in 1932, Foerste studied a small assemblage of fragmentary nautiloids from Middle Ordovician strata in the Trondheim area. In his report, Foerste describes *Endoceras stensetense, E. vehnense, E.* spp., *Cyrtendoceras?* sp., *Orthoceras katuglåsense, Geisonoceras strandi, Cycloceras kiaeri, C. hoelandense, C. trondhjemense,* and *Palaeonautilus? broeggeri* from strata of the Hovind group, which strata are probably equivalent in age to some part of the Ogygiocaris Series of the Oslo Region. The types of Foerste's several species are kept in Oslo, but they are so poorly preserved that it is indeed difficult to compare any of the material at hand with them. Subglobular trocholitids like those Foerste refers to *Palaeonautilus* appear to be restricted to the upper part of the Ogygiocaris Series in the Oslo Region and to generally equivalent strata in Estonia. Although the broadly expanded, rather deeply involute conch may justify generic distinction (*i. e., Palaeonautilus* rather than *Trocholites*) for these forms, I am following the more conservative practice of placing them in *Trocholites*, to which they are very closely related. Regardless of such taxonomic perplexities, however, trocholitids such as these appear to be restricted to a fairly limited horizon in the Scando-Baltic province and are, for that reason, fairly good indices to the faunal realm and the general age of the strata from which they are collected.

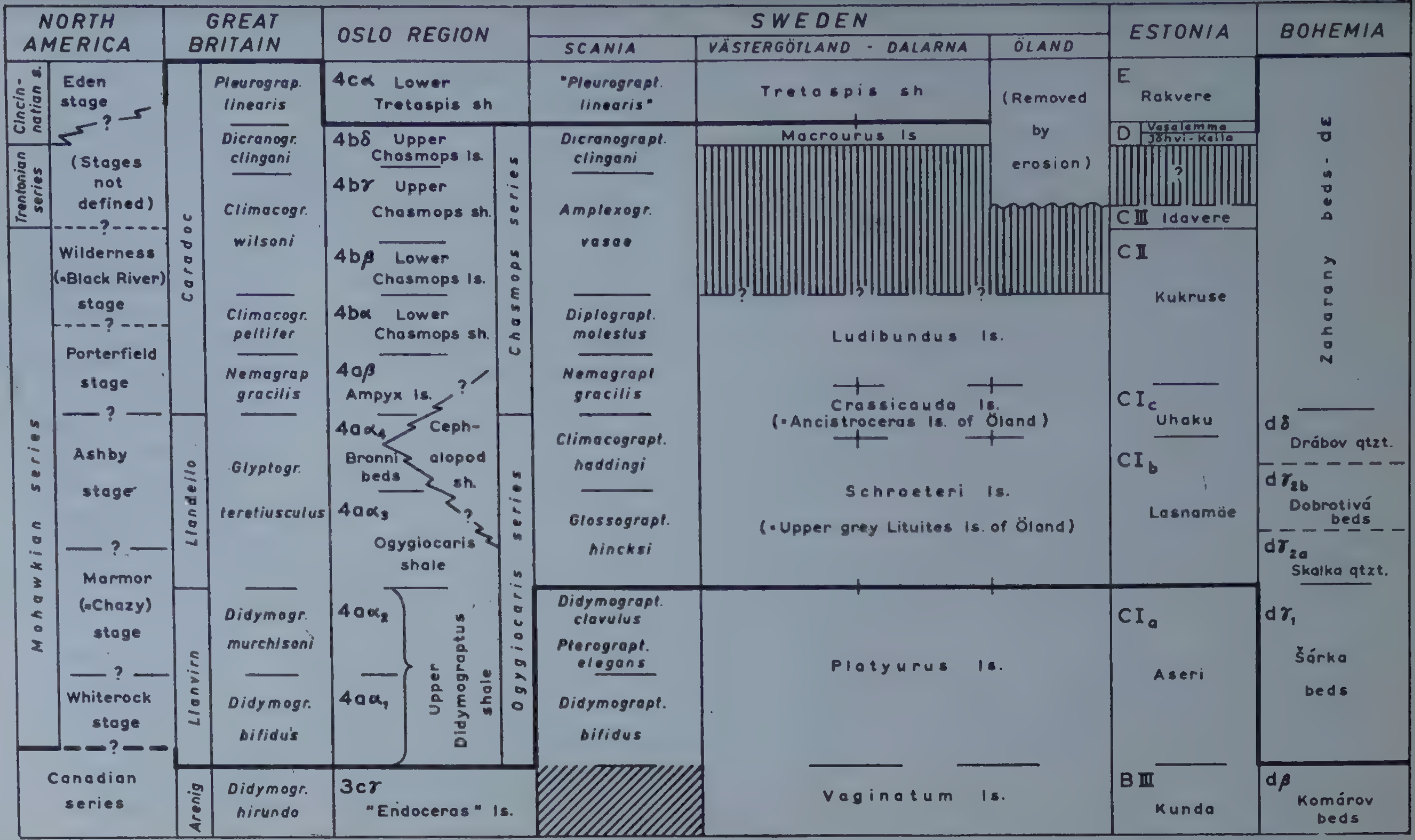
It should be mentioned that, in 1930 (p. 6) Hedström figured and tentatively indentified representatives of *Endoceras* sp., *Orthoceras* sp., *Discoceras?* sp., and *Trocholites?* sp. from a serpentine conglomerate in the Otta Valley of central Norway. The coiled cephalopods almost certainly belong in *Estonioceras* and *Plectoceras* (rather than in *Discoceras* and *Trocholites*), hence, as Hedström concluded, the fauna represented is probably of Lower, rather than Middle Ordovician age. His conclusions as to age are strengthened by the fact that undescribed collections from this same conglomerate contain a representative of *Piloceras* and several annulated forms reminiscent, at least, of *"Cyclendoceras" vaginatum* (Schlotheim).

DISTRIBUTION AND STRATIGRAPHIC SIGNIFICANCE

It has been generally agreed that no detailed discussion of correlation with respect to the Middle Ordovician rocks of the Oslo Region would be undertaken until all of the principal fossil groups have been studied. The following remarks, then pertain only to the distribution of Middle Ordovician cephalopods within the Oslo Region and to the probable significance of this distribution stratigraphically. Table I shows, schematically, the Middle Ordovician stratigraphic units of the Oslo Region and their probable equivalents elsewhere. It has been compiled largely from the literature and is to be regarded as highly provisional. This table is included, however, for the benefit of those not familiar with Scando-Baltic stratigraphy so that the cephalopods described in the present report may be understood in general stratigraphic context. Table II shows the distribution, by stratigraphic units and districts, of the cephalopods now known to occur in the Middle Ordovician strata of the Oslo Region.

As Størmer (1953, p. 112, etc.) and Spjeldnæs (1957, p. 196) have pointed out, the Oslo Region appears to have been differentiated into a number of rather distinct lithological and faunal subprovinces

TABLE I. Correlation of Middle Ordovician formations and zones



NORTH AMERICA		GREAT BRITAIN		OSLO REGION		SWEDEN: SCANIA	SWEDEN: VÄSTERGÖTLAND - DALARNA	SWEDEN: ÖLAND	ESTONIA	BOHEMIA
Cincinnatian s.	Eden stage ?	Caradoc	Pleurograp. linearis	4cα Lower Tretaspis sh		"Pleurograpt. linearis"	Tretaspis sh	(Removed by erosion)	E Rakvere	Zahorany beds - dε
Trentonian series	(Stages not defined) ?		Dicranogr. clingani	4bδ Upper Chasmops ls.	Chasmops series	Dicranograpt. clingani	Macrourus ls		D Vasalemma Jõhvi-Keila ?	
			Climacogr. wilsoni	4bγ Upper Chasmops sh.		Amplexogr. vasae			C III Idavere	
Mohawkian series	Wilderness (=Black River) stage ?			4bβ Lower Chasmops ls.			?		C II Kukruse	
	Porterfield stage ?		Climacogr. peltifer	4bα Lower Chasmops sh.		Diplograpt. molestus	Ludibundus ls.			
			Nemagrap gracilis	4aβ Ampyx ls. ?		Nemagrapt gracilis	Crassicauda ls. (=Ancistroceras ls. of Öland)		C Ic Uhaku	
	Ashby stage ?	Llandeilo	Glyptogr. teretiusculus	4aα4 Bronni beds Cephalopod sh. ? 4aα3 Ogygiocaris shale	Ogygiocaris series	Climacograpt. haddingi Glossograpt. hincksi	Schroeteri ls. (=Upper grey Lituites ls. of Öland)		C Ib Lasnamäe	dδ Drábov qtzt. dγ2b Dobrotivá beds dγ2a Skalka qtzt.
	Marmor (=Chazy) stage ?	Llanvirn	Didymogr. murchisoni	4aα2 Upper Didymograptus shale		Didymograpt. clavulus Pterograpt. elegans	Platyurus ls.		C Ia Aseri	dγ1 Šárka beds
	Whiterock stage ?		Didymogr. bifidus	4aα1		Didymograpt. bifidus				
Canadian series		Arenig	Didymogr. hirundo	3cγ "Endoceras" ls.		▨	Vaginatum ls.		B III Kunda	dβ Komárov beds

Table I. Correlation of Middle Ordovician formations and zones. Correlations are generalized; boundaries are only approximate. Scando-Baltic correlations from Størmer (1953), Jaanusson (1945, 1947), Jaanusson & Strachan (1954), Kaljo, *et al.*, (1956). Subdivisions of North American Mohawkian after Cooper (1956). Heavy black lines represent Lower/Middle and Middle/Upper Ordovician boundaries as recognized in the areas represented by the vertical columns.

Nautiloid genera and species	Horizons														Districts						
	$4a\alpha_{1-2}$	$4a\alpha_3$	Cephalopod sh.	$4a\beta$	$4b\alpha$	$4b\beta$	Coelosphaeridium beds	$4b\gamma$	Cyclocrinus beds	$4b\delta_{1-2}$	Encrinite ls.	Sphaeronid ls.	Gagnum sh.	Mjøsa ls.	Oslo—Asker	Gjerpen—Langesund	Ringerike	Hadeland	Toten	Nes—Hamar	Ringsaker
Eobactrites sandbergeri	X	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
Bathmoceras norvegicum ...	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—
Dideroceras wahlenbergi	X	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
Endoceras spp.	—	—	X	X	X	—	—	—	—	X	—	—	—	—	X	—	X	—	—	X	—
Vaginoceras sp.	—	—	X	?	—	—	—	—	—	—	—	—	—	—	?	—	—	—	—	X	—
Cyrtendoceras, n. sp.	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—
Nybyoceras holmi..........	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—
Nybyoceras sp.	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—
Ormoceras kiaeri	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	X	X
Hoeloceras helgoeyense........	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—
Hoeloceras askeri	—	—	—	—	—	X	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
Sactorthoceras sp...........	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—
Polygrammoceras sp.	—	—	—	—	?	?	—	?	—	?	—	—	—	—	X	—	—	—	—	—	—
Protokionoceras strandi.....	—	—	—	—	?	?	—	?	—	?	—	—	—	—	X	—	—	—	—	—	—
Geisonoceras scabridium (ex Holtedahl, 1909)	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	X	—
Kionoceras suave (ex Holtedahl, 1909)	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—
"*Kionoceras*" *sp.*	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—
Stereoplasmoceras longicameratum	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	X	—
Stereoplasmocerina lineata..	—	?	X	—	—	—	—	—	—	—	—	—	—	—	?	—	—	—	—	X	—
Stereoplasmocerina approximata	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—
Ctenoceras sp. A	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X	X	—
Ctenoceras sp. B	—	—	—	—	X	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
Ephippiorthoceras frognoey-	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	X	—	—	—	—

Probillingsites, n. sp.	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—
Oncoceras sp.	—	—	?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	?	—
Beloitoceras stoermeri	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—
Allumettoceras mjoesense	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—
Allumettoceras sp. (ex Holtedahl, 1909)	—	—	—	—	—	—	—	—	?	—	—	—	—	—	—	—	—	—	—	?	—
Tripteroceras? problematicum	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—
Valcouroceras? holtedahli	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—
Diestoceras sp.	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	X	—	—	—	—
Trocholites depressus	X	—	X	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	X	—
Trocholites contractus	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—
Trocholites hospes	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	X	—
Discoceras arcuatum	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X	—
Discoceras boreale	—	—	X	?	—	—	—	—	—	—	—	—	—	—	X	—	—	—	X	X	—
D. boreale amplicameratum	—	—	—	X	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
Discoceras depressum	—	?	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
Discoceras fleischeri	—	—	—	—	—	—	—	—	—	—	X	—	X	—	—	X	—	X	—	—	—
Discoceras ievesense	—	—	—	—	—	X	—	—	X	—	—	—	—	—	X	—	—	—	?	X	—
Discoceras rarospira	—	—	—	—	—	?	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
Ancistroceras undulatum	—	—	?	X	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	?	—
Angelinoceras sp.	—	—	—	X	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
Rhynchorthoceras helgoeyense	—	—	X	—	?	?	—	—	—	—	—	—	—	—	X	—	—	—	—	X	?
Rhynchorthoceras angelini?	—	?	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
Lituites lituus?	—	?	—	X	—	—	—	—	—	—	—	—	—	—	X	—	—	X	—	—	—
Lituites perfectus	—	?	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	X	—
Trilacinoceras discors	—	X	X	—	—	—	—	—	—	—	—	—	—	—	X	—	—	X	—	X	—
Trilacinoceras norvegicum	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—
Trilacinoceras sp.	—	—	—	X	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
Cyclolituites lynnensis	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	X	—
Cyclolituites kjerulfi	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—
Tyrioceras? sp.	—	—	—	—	—	X	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
Ruedemannoceras? sp.	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—
Broeggeroceras contractum	—	—	—	—	—	X	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
Strandoceras strandi	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—
Strandoceras sp.	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	X	—	—	—

during Middle Ordovician time. The faunal differentiation, as might be expected, is strikingly shown by those animal groups which lived for the most of their lives in close association with the sea bottom, but is not particularly evident in the presumably more highly mobile nautiloid faunas. There are, to be sure, lateral differences in abundance within essentially contemporaneous strata, but, insofar as I can determine, no subprovincial distinctions seem to have been developed by the nautiloids themselves.

At least a few cephalopods occur in one or more of the several facies in each of the nine substages which comprise the Middle Ordovician Ogygiocaris and Chasmops Series in the Oslo Region. Nautiloids are most abundant, however, in the so-called Cephalopod shale, which forms the upper part of the Ogygiocaris Series in districts adjacent to Lake Mjøsa, and in the perhaps partly equivalent Ampyx limestone, the basal substage of the Chasmops Series. This gross distribution suggests that for only a short part of Middle Ordovician time, and in a rather restricted portion of the Oslo Region, were ecological conditions particularly favorable to the development of a large and varied cephalopod fauna.

For the most part, the cephalopods now known from the Ogygiocaris Series and from the early part of the superjacent Chasmops Series represent a fauna known best from the Scando-Baltic province and, perhaps, restricted largely to it. This general fauna, of which the bizarre lituitids and the primitive trocholitid, *Discoceras*, are the most striking elements, is unknown in North America. Genera suggesting it, however, have been reported from China, Manchuria, Korea, Australia, and Argentina, and it has a few features in common with the scanty early Middle Ordovician faunas described long ago by Barrande from central Europe. A few species from the upper part of the Ogygiocaris Series have close affinities to largely contemporaneous forms known best at present from eastern United States and Canada. The number of these forms is small, however, and their stratigraphic significance is difficult to assess.

With the exception of a few lituitids and the ubiquitous and apparently indigenous *Discoceras*, the nautiloids from the post-Ampyx limestone portion of the Chasmops Series are referable to, or most closely related to, genera which are known to have a rather wide distribution in the Northern Hemisphere. This rather cosmopolitan cephalopod fauna is known from numerous localities in eastern and central United States and Canada, and representatives of it have also been reported from the Canadian arctic, Greenland, and Kazakhstan.

More detailed, or particularly meaningful comparisons of the several cephalopod faunas of the Norwegian Middle Ordovician with those described from other parts of the world, or, indeed, with those previously reported from the balance of the Scando-Baltic province, is difficult for a number of reasons. Most of the Scando-Baltic nautiloid species were named many years ago, at a time when a short description of conch shape and ornamentation was considered to be sufficiently diagnostic. A few of these have been carefully restudied, but the majority of them can not now be referred with certainty to any known generic group and will probably remain unrecognizable, even specifically, until they are redescribed in terms of their internal structures. Furthermore, Scando-Baltic stratigraphic concepts and terminology have changed considerably within the last several decades, hence in many cases it is difficult to interpret the stratigraphic information which accompanies the older specific descriptions. In this connection, it should also be noted that the types of many Middle Ordovician nautiloid species were collected from glacial drift boulders in Poland and Germany and it is possible, for the most part, to make only reasoned "guesses" as to the stratigraphic interval from which these boulders were derived. For these reasons, and for the additional reason that precise stratigraphic information is unavailable for many of the Norwegian nautiloids herein described, the following remarks are necessarily generalized. They will almost certainly need revision, at least in part, when our knowledge of both the provincial and extra-provincial distribution of the species involved becomes more adequate.

Upper Didymograptus Shale ($4a\alpha_{1-2}$). Only a few identifiable nautiloids have been collected from this unit in the Oslo Region, and all of them come from the Oslo—Asker district. These specimens belong in *Eobactrites sandbergeri* (Barrande), *Dideroceras wahlenbergi* (Foord), and *Trocholites depressus* (Eichwald). *Eobactrites* has not previously been reported from the Scando-Baltic province, being known heretofore only from the Šàrka beds of Bohemia. *Dideroceras wahlenbergi* (Foord) has been recorded from rocks which range in age from upper Arenig

(Vaginatum limestone) through Llandeilo (Upper Gray Orthoceras limestone), although it is probable that specimens from all of these horizons do not belong in the same species. The genus is also represented in Manchuria, Korea, and Argentina, in rocks of approximately the same age. The type of *Trocholites depressus* (Eichwald) comes from the Lasnamäe limestone (C_Ib) of Estonia, but, in Norway at least, this species appears to range throughout the Ogygiocaris Series. It might be pointed out, however, that meaningful specific boundaries are difficult to establish in these small trocholitids and it is probable that little stratigraphic importance should be attached to them.

This small nautiloid assemblage does not seem to be particularly characteristic of any of the several early Middle Ordovician horizons in the Scando-Baltic region. The only form restricted to it is *Eobactrites sandbergeri* (Barrande), which also seems to have a rather limited range in Bohemia.

Ogygiocaris Shale ($4a\alpha_3$). Several of the specimens in the collections herein described were collected from strata representing some part of this interval. These nautiloids are referable to *Trilacinoceras discors* (Holm), *Trilacinoceras norvegicum* Sweet, n. sp., *Stereoplasmocerina lineata* Sweet, n. sp., *Discoceras depressum* Sweet, n. sp., *Rhynchorthoceras angelini* (Boll)?, *Lituites lituus* Montfort?, and *Lituites perfectus* Wahlenberg. *Lituites discors* Holm is a very distinctive species which I am referring to a new genus, *Trilacinoceras*. In Sweden, and particularly on the Island of Öland, this species occurs near the base of the Schroeteri limestone and in Norway, it is most abundantly represented in the Cephalopod shale of the Nes—Hamar district. *Trilacinoceras norvegicum* Sweet, n. sp., appears to be morphologically intermediate between *Lituites törnquisti* Holm and *Trilacinoceras discors* (Holm), hence its appearance in the upper part of the Ogygiocaris shale suggests that those strata are probably somewhat younger than the upper part of the Platyurus limestone (zone with *Illaenus* aff. *sulcifrons*) in Sweden to which *L. törnquisti* seems to be restricted (Jaanusson & Mutvei, 1953). *Rhynchorthoceras angelini* (Boll), with which several of the Ogygiocaris shale nautiloids may be conspecific, occurs in the upper Platyurus limestone of Sweden (Jaanusson & Mutvei, *op. cit.*), whereas *Lituites lituus* and *L. perfectus* seem to be most characteristic of the Schroeteri limestone on Öland. *Discoceras* *depressum* Sweet, n. sp., is most closely related morphologically to *D. damesi* (Schröder,) the type and only known specimen of which came from a drift boulder in Germany. According to Schröder (1891, p. 20) this boulder also contained *Glyptosphaerites leuchtenbergi*, a cystidean species listed only from the lower part of the Uhaku limestone of Estonia by Kaljo *et al.* (1956, p. 14), but reported by Regnéll (1945, p. 156) to range from the Vaginatum limestone into the Uhaku limestone of the Baltic provinces. All of the Swedish specimens of this species, however, are from the Gigas-Platyurus interval. The types of *Stereoplasmocerina lineata*, n. sp., are from the Cephalopod shale of the Nes—Hamar district.

A majority of the nautiloids now known from the Ogygiocaris shale can be said to suggest a correlation of this unit with at least part of the Schroeteri limestone of Sweden. In addition, the fact that several species from the Ogygiocaris shale are also found in the Cephalopod shale suggests that these two units may, in part, be facies equivalents of one another.

Bronni Beds ($4a\alpha_4$). Cephalopods are not known to occur in the typically sandy facies of this unit in the Oslo—Asker district, and it is either absent or its boundaries are difficult to define in other parts of the Oslo Region. Presumably (*see* Størmer, 1953), this substage is represented by at least part of the richly fossiliferous Cephalopod shale in the districts adjacent to Lake Mjøsa.

Cephalopod Shale. This unit is restricted in its development to the districts surrounding Lake Mjøsa (Hadeland, Toten, Nes—Hamar, and Ringsaker). It is underlain by strata belonging to the Ogygiocaris shale and overlain by the sparingly fossiliferous Robergia beds, which are probably equivalent to some part of the Ampyx limestone as it is developed in other parts of the Oslo Region. For these reasons, the Cephalopod shale is probably in large part equivalent to the Bronni substage of the Oslo—Asker district. However, it contains nautiloids which are also found in the typical facies of both the Ogygiocaris shale and Ampyx limestone. These facts suggest that, in addition to rocks deposited contemporaneously with the Bronni beds of the Oslo—Asker district, the Cephalopod shale contains strata equivalent to the upper part of the typical Ogygiocaris shale and the lower part of the type Ampyx limestone.

The Cephalopod shale has yielded a great majority of the nautiloids described in this report. The following genera and species are now known to be represented in this unit:

Bathmoceras norvegicum, n. sp. *Endoceras* sp. *Vaginoceras* sp. *Cyrtendoceras*, n. sp. *Nybyoceras holmi*, *n.* sp. *Nybyoceras* sp. *Hoeloceras helgoeyense*, n. gen. & sp. *Sactorthoceras* sp. *Stereoplasmoceras longicameratum*, n. sp. *Stereoplasmocerina lineata*, n. sp. *Stereoplasmocerina approximata*, n. sp. *Ctenoceras* sp. A. *Stereospyroceras?* sp. *?Oncoceras* sp. *Allumettoceras mjoesense*, n. sp. *Valcouroceras? holtedahli*, n. sp. *Trocholites depressus* (Eichwald) *Trocholites contractus* Schröder. *Trocholites hospes* (Remelé) *Discoceras arcuatum* (Lossen) *Discoceras boreale*, n. sp. *Ancistroceras undulatum* Boll? *Rhynchorthoceras helgoeyense*, n. sp. *Trilacinoceras discors* (Holm) *Cyclolituites lynnensis* (Kjerulf) *Cyclolituites kjerulfi*, n. sp. *Ruedemannoceras?* sp. *Strandoceras strandi*, n. sp.

Most of these species are represented in collections at hand by only a few specimens, and quite a number of them belong in genera not heretofore reported from Middle Ordovician rocks in the Scando-Baltic region. Representatives of the several lituitid genera are, perhaps, the most abundant nautiloids in the Cephalopod shale, but *Discoceras* is not rare, and straight forms referable to *Sactorthoceras*, *Stereoplasmoceras*, and *Stereoplasmocerina* are numerous.

Bathmoceras has a known stratigraphic range from late Lower Ordovician into the early Middle Ordovician, but previously described species of this genus all seem to be somewhat older than the new form herein recognized. *Endoceras* and *Vaginoceras*, in their previously rather broadly interpreted form are long-ranging genera characteristic only of the Middle and Upper Ordovician. Although both genera have recently been restricted in scope, it is difficult, at present, to know which of the many described species (other than the types) should be retained in either of them; hence it is not possible to assign the Cephalopod shale specimens any particular stratigraphic significance. *Cyrtendoceras* is a little-known genus which is apparently restricted to the Scando-Baltic province. The age of known *Cyrtendoceras* species suggests, however, that the genus is confined to the early Middle Ordovician; that is, to that part of Middle Ordovician time represented by the Platyurus-Schroeteri interval in Sweden.

The type species of *Nybyoceras* is from the Upper Ordovician Lyckholm beds of Estonia, but congeneric species are known to occur in rocks as old as the Chazy limestone (Marmorian) of the United States. It is to these older species that the new form herein described seems to be most closely related. *Hoeloceras* is a lambeoceratid, intermediate in internal structure between *Gonioceras* Hall and *Lambeoceras* Foerste. The Gonioceratidae do not make their appearance until the Marmorian in North America; *Lambeoceras* is confined to Upper Ordovician rocks in North America.

Sactorthoceras, *Stereoplasmoceras*, and *Stereoplasmocerina* are straight forms based on types from the early Middle Ordovician of China and Korea. Species of these genera have not heretofore been recorded from parts of the world other than the type localities, although Flower (1946, p. 168) reports that *Sactorthoceras* is known in the Chazy and Black River limestones of the Champlain Valley in northeastern United States.

Allumettoceras, *Stereospyroceras*, *Valcouroceras*, *Trocholites*, and *Ruedemannoceras* are all known from the Chazy limestone of Marmor age in the northeastern part of the United States. *Allumettoceras* ranges upwards throughout the Middle and Upper Ordovician, as does *Trocholites*, but *Stereospyroceras*, *Valcouroceras*, and *Ruedemannoceras* are at present known only from the Marmorian. Small species of *Trocholites*, like *T. depressus* and *T. contractus* of the Scando-Baltic province, *T. ruedemanni* and *T. gracilis* of the North American Chazy limestone, and *T. ammonioides* from the Chikunsan beds of Makkol, Manchuria, appear to be characteristic of the early Middle Ordovician, however, and, at the present time, seem to be reasonably good indices to it.

Ancistroceras ranges from late Lower Ordovician into at least the early part of the late Middle Ordovician. *A. undulatum* Boll appears, however, to be most characteristic of the interval represented by the Schroeteri and Crassicauda limestones of Sweden and the Lasnamäe and Uhaku limestones of Estonia. *Trilacinoceras discors* (Holm), as noted previously, is characteristic of a zone in the lower part of the Schroeteri limestone of Öland, but representatives of it and of a closely related species, *T. norvegicum*, n. sp., are also found in the immediately subjacent Ogygiocaris shale of the Oslo Region. *Cyclolituites lynnensis* (Kjerulf) is most closely comparable to *C. lynceus* Holm, from the Schroeteri limestone of Öland; *C. kjerulfi*, n. sp., has no close counterpart among previously described species of *Cyclolituites. Rhynchorthoceras helgoeyense*, n. sp., is also considerably different from other known representatives of that genus, hence its stratigraphic significance is difficult to assess.

The dominantly provincial elements of the Cephalopod shale nautiloid fauna indicate a correlation of this unit with the Schroeteri and Crassicauda limestones of Sweden and with the essentially equivalent Lasnamäe and Uhaku limestones of Estonia. The few forms which appear to be referable to, or closely related to, North American genera suggests that the Cephalopod shale is perhaps intermediate in age between the Marmor and the Wilderness stages.

Ampyx limestone (4aβ). In the Oslo—Asker district, this unit has yielded nautiloids referable to *Endoceras* sp., *Discoceras boreale*, n. sp., *D. boreale amplicameratum*, n. subsp., *Ancistroceras undulatum* Boll, *Angelinoceras* sp., *Lituites lituus* Montfort?, and *Trilacinoceras* sp. The gross stratigraphic significance of these genera has been discussed in connection with other substages, but it seems appropriate to emphasize at this point the similarity between the Ampyx limestone and Cephalopod shale nautiloids. This may be taken to suggest that the typical Ampyx limestone of the Oslo—Asker district is in part equivalent to the Cephalopod shale of the northern districts.

Lower Chasmops Shale (4bα). Only a few cephalopods are known from this horizon, but they differ considerably from those which precede them stratigraphically. Known specimens are referable to *Endoceras* sp., "*Kionoceras*" sp., *Ctenoceras* sp. B, *Gorbyoceras?* sp., *Beloitoceras stoermeri*, n. sp., and *Tripteroceras? problematicum*, n. sp. In addition, a specimen of *Rhynchorthoceras helgoeyense*, n. sp., may have been derived from this unit. None of these nautiloids offer any particularly diagnostic stratigraphic information, but they seem to represent the incursion into the Oslo Region of cephalopods generally thought to be characteristic of the so-called boreal, or "arctic" faunas. Spjeldnæs (1957, p. 199) makes the interesting suggestion that ashfalls at about this time may have destroyed the previously indigenous brachiopod faunas of the Oslo Region, and that subsequent immigration from other faunal provinces served to produce the rather abrupt changes in faunal composition noted at this level.

Lower Chasmops Limestone (4bβ). The few nautiloids known from the Lower Chasmops limestone, referable to *Hoeloceras askeri*, n. gen. & sp., *Probillingsites*, n. sp., *Discoceras ievesense* (Balaschov), *D. rarospira* (Eichwald), *Tyrioceras?* sp., and *Broeggeroceras contractum*, n. gen. & sp., seem to indicate a return to the Oslo Region of several provincial, Scando-Baltic elements. The *Probillingsites*, however, is a boreal indicator, and *Broeggeroceras* is most closely related to genera characteristic of the boreal nautiloid faunas. The type of *Discoceras ievesense* (Balaschov) comes from the Jõhvi limestone of Estonia, and other representatives of the same species are found in the somewhat younger Cyclocrinus beds of the Nes—Hamar district. This suggests that the species has a rather considerable stratigraphic range and it is, for that reason, difficult to assign it any particular importance in an age-evaluation of the Lower Chasmops limestone nautiloids. *Discoceras rarospira* (Eichwald) is, according to Balaschov (1953a, p. 212) a very long-ranging species, extending from the Aseri limestone into the Keila limestone of Estonia. Kaljo, *et. al.* (1956, p. 39) list the species only from the Idavere of Estonia, however, and this unit is probably not much different in age from the Lower Chasmops limestone.

Coelosphaeridium Beds. These strata, restricted to the Hadeland, Nes—Hamar, and Ringsaker districts, have yielded only one cephalopod, which was referred by Holtedahl (1909) to *Orthoceras scabridium* Angelin. I have not been able to locate this specimen, but the species (now generally referred to *Geisonoceras* Hyatt) was originally described from Öland, Sweden, and is listed by Lindström (1888) as occurring in the Upper Red and Upper Gray Orthoceras limestones — both of which are certainly considerably older than the Coelosphaeridium beds.

Upper Chasmops Shale (4bγ). No cephalopods are known to me from the typical facies of this unit; however, a few occur in the essentially equivalent, more calcareous Cyclocrinus beds of the Nes—Hamar district.

Cyclocrinus Beds. Holtedahl (1909) reported *Orthoceras suave* Angelin and *Orthoceras cuneolus* Eichwald from this unit in the Nes—Hamar district, and a representative of *Discoceras ievesense* (Balaschov) is herein described from the same beds. *Orthoceras suave* Angelin probably belongs in *Kionoceras* Hyatt, and Teichert (1930) reports that the types of *Orthoceras cuneolus* Eichwald are referable to *Allumettoceras* Foerste. I have not located either of Holtedahl's specimens, but little significance can be attached to the cited identifications, for both species have been interpreted rather broadly and many probably unrelated specimens from different parts of the Scando-Baltic province have been placed in them in the past. The types of both species, furthermore, came from Upper Ordovician strata. The type of *Discoceras ievesense* (Balaschov), which also occurs in the Lower Chasmops limestone, is from the Jõhvi limestone of Estonia. It is, apparently, a rather long-ranging species. In addition to these identifiable specimens, it should be mentioned that the collections at hand contain two fragmentary orthoceracones (P.M.O. 64729, 64735) of somewhat depressed cross-section which may represent *Allumettoceras*, but can not be placed in that genus with certainty.

Upper Chasmops Limestone ($4\delta_{1\text{-}2}$). In the Ringerike district, this unit has yielded *Ephippiorthoceras frognoeyense* Strand and *Diestoceras* sp., whereas *Endoceras* sp., and small generically unidentifiable lituitids and orthoceracones are known from the same strata in the Oslo—Asker district. Strand (1933) has figured and discussed both *Ephippiorthoceras frognoeyense* and the lituitids. None of these forms have any particular extra-provincial significance stratigraphically, but the *Ephippiorthoceras* and *Diestoceras* may be said to indicate that the Oslo Region continued to maintain arctic connections during this time.

Encrinite Limestone. This unit forms the upper part of the Chasmops Series in the Gjerpen—Langesund district, and is thought to be essentially equivalent in age to the Upper Chasmops limestone. The Encrinite limestone has yielded a specimen referable to *Discoceras fleischeri*, n. sp., and an incomplete, generically indeterminate lituitid similar to, but some larger than, the ones Strand (1933, p. 52) described from the overlying Tretaspis limestone in the same district. *Discoceras fleischeri* is strikingly similar in form to a specimen from Silliman's Fossil Mount, Baffin Island, described as "*Discoceras* aff. *D. canadense* (Whiteaves)" by Miller, *et al.* (1954), and the two may well be conspecific. The Baffin Island strata which yielded the specimen Miller and his colleagues studied are considered by them to be early Upper Ordovician in age.

Sphaeronid Limestone. This unit, which is a local development of the lower part of the Upper Chasmops limestone in the northern portion of the Hadeland district, has yielded but a single cephalopod. This small specimen is referable to *Strandoceras* Flower. It can not be associated definitely with any described species of that genus, but it is not unlike *S. tyriense* (Strand) from the Upper Ordovician Tretaspis and Gastropod limestones of the Oslo Region.

Gagnum Shale. Only one nautiloid, referable to *Discoceras fleischeri*, n. sp., has been collected from the Gagnum shale, a shaly development of the Upper Chasmops limestone in the Hadeland district. *D. fleischeri* also occurs in the Encrinite limestone, a fact which tends to strengthen the previously expressed opinion that these units are of essentially the same age.

Mjøsa Limestone. Although this reefy facies of the Upper Chasmops limestone is richly fossiliferous, it has yielded only a few cephalopods. These specimen are referable to *Ormoceras kiaeri*, n. sp., and to *Discoceras* sp. The *Discoceras* may be referable to *D. fleischeri*, n. sp., but can not be placed there with certainty. *Ormoceras kiaeri* is rather common in the Mjøsa limestone, but it is a rather generalized form and, at least at present, of little value stratigraphically.

SYSTEMATIC PALEONTOLOGY

Ideas with regard to a natural classification of the nautiloid cephalopods have changed considerably in the last half century, and have been particularly refined during the past decade. It is customary to regard the Nautiloidea and their later derivatives, the Ammonoidea, as groups of equivalent taxonomic rank, and the two groups together are generally distinguished from all other cephalopods by placing them in the Subclass Tetrabranchiata (rather than Dibranchiata). It should be mentioned, however, that a subdivision of the Cephalopoda into Tetra-, and Dibranchiata is based upon the number of gills in living representatives of these subclasses, and reference of the largely fossil nautiloids and the wholly extinct ammonoids to the Tetrabranchiata can be justified only by the fact that the sole modern representative of this Subclass, *Nautilus*, has 4, rather than 2 gills.

Under the impression that the Cephalopoda were to be considered a Subphyllum of the Mollusca, Flower & Kummel (1950) subdivided the Nautiloidea into 14 orders, primarily on the basis of the siphuncular structure. Recently, however, the authors of Part L of the "Treatise on Invertebrate Paleontology"(Arkell, *et al.*, 1957) have treated the Ammonoidea as an Order, and, since the Nautiloidea are presumably of equivalent taxonomic rank, it seems best to consider all nautiloids together as representing but a single Order. For this reason, those of Flower & Kummel's ordinal names which are pertinent to the following report are reduced to subordinal rank, and their endings are herein emended in conformity with the practice adopted in the "Treatise on Invertebrate Paleontology".

It has been recognized for more than half a century that, for the most part, the external form of the nautiloid conch is a rather unreliable guide to relationship and that a taxonomic scheme based upon shape alone does not very closely approximate an "ideal" classification, which should, insofar as possible, express phylogeny. Since only a few fundamental conch shapes are possible in the Nautiloidea, it is not surprising to find that they recur in many only distantly related stocks and at widely separated stratigraphic horizons. For this reason, particular taxonomic significance is now attributed to internal features of the conch, particularly to the siphuncle, muscle impressions, and cameral deposits, for the range of possible variation in these structures is considerably greater and, being internal, they were least susceptible to environmental influences. Reduced emphasis on conch shape should not be interpreted to mean, however, that this feature is of no systematic importance. The shape of the conch is variable within only small limits on the specific and generic levels, and several families and even suborders are characterized by similarly shaped conchs.

Largely on the basis of the siphuncular (including both endo-, and ectosiphuncular) structure, Flower & Kummel (1950) recognized 14 major nautiloid stocks, which included some 74 families. Subsequent to 1950, Flower (1955c, p. 245) has noted that the orders Nautilida and Centroceratida are so closely related that it seems inadvisable to separate them. Hence, at the present time, the Order Nautiloidea is thought to include 13 suborders, the majority of which are

Paleozoic in both origin and abundance. Eleven of the 13 suborders were established by or shortly after the beginning of the Middle Ordovician, and representatives of eight of them occur in the Middle Ordovician strata of the Oslo Region.

Terminology. As is the case in all other animal groups with which I am familiar, there has been a great deal of variation, and not a little confusion in the terminology used in the description of fossil nautiloids. Within recent years, however, the common terms have come to be employed in the same way by most writers, and, even though ". . . there are logical objections to the application to these animals of such terms as anterior, posterior, dorsal, and ventral, with what appears to be their customary meaning, . . . it can be justified on the basis of usage" (Miller & Furnish, in Arkell, *et al.*, 1957, p. *xx*). That is, if nautiloids are oriented for descriptive purposes in a manner anatomically comparable to that employed for pelecypods and gastropods, the adapical portion of the body is, indeed, dorsal, the cephalopodium ventral, the hyponomic side posterior, and the opposed side anterior, as Mutvei (1956, p. 179) insists they "must" be. However, it is doubtful if more than an few small, primitive nautiloids lived in such a position, hence the more familiar terminology is applied to the conch oriented in a living position (insofar as this can be determined) and the few anatomical terms commonly used are employed in a "functional" sense. For these reasons, the nautiloids which form the basis for the following report are described in terms whose meaning, with respect to fossil nautiloids, is well established and widely understood. Those not familiar with these terms are referred to Flower (1946, p. 57—68) who gives an excellent review of the major structural features of nautiloids, their development, and the terms applied to them for descriptive purposes. Teichert & Glenister (1954, p. 32—34) have prepared a chart and a glossary explaining the terminology of septal necks. In their report, they also introduce several new descriptive terms, a few of which are employed in the following descriptions.

The catalogue designations, P.M.O. and R.M., used in the descriptive and illustrative sections of this report refer, respectively, to the Paleontological Museum, Oslo, and the Palæozoological Division of the State Museum of Natural History (Naturhistoriska Riksmuseet), Stockholm.

DESCRIPTIONS.

Class Cephalopoda Leach, 1817

Order Nautiloidea Zittel, 1884

Suborder Ellesmeroceratina Flower, 1950

[*nom. transl.* herein (*ex* Ellesmeroceratida Flower, 1950).]

FAMILY Baltoceratidae Kobayashi, 1935.

GENUS *Eobactrites* Schindewolf, 1932.

Type species: Bactrites sandbergeri Barrande, 1867.

In 1933 (p. 72), Schindewolf defined *Eobactrites* as "Bactritidae mit kreisrundem Gehäusequerschnitt, Lobenlinie mit schmalem, zungenförmigem Siphonallobus, im übrigen völlig gerade. Anwachsstreifen nahezu geradlinig, mit nur angedeutetem sehr breiten, flachen Sinus auf der Siphonalseite."

Although *Eobactrites* was assigned to the Bactritidae of Hyatt by Schindewolf, he shows it (1942, p. 356) in his phylogenetic chart of the Cephalopoda as being an independent, Ordovician development from the "Orthoceracea", and not connected directly with the line which, he believes, led from *Bactrites* to the Goniatitacea in the upper part of the Silurian. The genus is indeed similar to *Bactrites* Sandberger, differing from it only in that the section is circular rather than somewhat depressed and the ventral lobe of the suture is deeper and more acute adapically.

Many writers follow Schindewolf in referring *Eobactrites* to the Bactritidae; however, it was placed with question in the Baltoceratidae by Flower (in Flower & Kummel, 1950, p. 608) and that procedure is followed here. It should be noted, however, that the taxonomic position of forms like these is a much debated subject. They are regarded by some as primitive ammonoids whereas others tend to believe that they are orthochoanitic nautiloids with small, marginal siphuncles. A third possibility has been suggested by Shimansky (1954, p. 70, *et seq.*), who refers the families Bactritidae (in which he includes *Eobactrites*), Parabactritidae, and Ctenobactritidae to a new order, the Bactritoidea, conceived to be intermediate between, but equal in rank to the Nautiloidea and Ammonoidea.

Insofar as I have been able to ascertain, *Eobactrites* is known only from the type species, and from a single stratigraphic horizon, the Šàrka beds of Bohemia. The genus is closely similar to both *Bactroceras* Holm and *Baltoceras* Holm [=? *Cochlioceras* Eichwald], which are, in turn, closely related to each other. Both *Bactroceras* and *Baltoceras* have tubular ventral siphuncles which are only slightly separated from the margin of the conch; in *Baltoceras*, the siphuncle is relatively large in proportion to the conch diameter, whereas in *Bactroceras* and *Eobactrites* it is quite small.

Eobactrites sandbergeri (Barrande).

Plate 2, figures 1, 3, 5.

1867. *Bactrites sandbergeri* BARRANDE, Système Silurien du centre de la Bohême, II. Céphalopodes. Texte 1, p. 49.
1868. *Bactrites sandbergeri* BARRANDE, *Idem*, pl. 245, fig. 9—21.
1870. *Bactrites sandbergeri* BARRANDE, *Idem*, pl. 413, fig. 10—14.
1932. *Eobactrites sandbergeri* SCHINDEWOLF, Paläont. Zeitschr., Bd. 14, p. 174.
1933. *Eobactrites sandbergeri* SCHINDEWOLF, Preus. Geol. Landesanst., Abh., N. F., Hft. 148, p. 72, pl. 4, fig. 9a, 9b.

Material: Three specimens, all fragmentary, and perhaps representing isolated parts of the same individual. All are internal molds. P.M.O. I 1812a—c.

Description: Conch long, slender, "pencil-shaped" expanding at an angle of less than 8° adapically. Cross-section circular. Camerae long, about 2 occurring in a length equivalent to the conch diameter. Septa subhemispherical, with an adapical convexity equivalent to somewhat more than half the length of a camera. Sutures straight and directly transverse to the long axis of the conch except mid-ventrally where they are sharply deflected adapically to form deep, V-shaped lobes. Siphuncle marginal in position, tubular in form, and with a diameter only one-eighth to one-tenth that of the conch. Septal necks are orthochoanitic and the connecting rings are cylindrical; detailed structure not obtainable from pyritized specimens at hand.

Remarks: All of the specimens I am studying agree closely with the ones from Bohemia figured by Barrande and Schindewolf, and are associated with them without question. Other evidence suggests that the Upper Didymograptus shale and the Šàrka beds of Bohemia are of essentially the same age, and the presence in both strata of *Eobactrites* strengthens this correlation.

Distribution: Šàrka beds of Bohemia; Upper Didymograptus shale ($4a\alpha_{1-2}$), north of Villa Victoria and south of Bygdøy sjøbad, Oslo.

FAMILY Bathmoceratidae Holm, 1899.

GENUS *Bathmoceras* Barrande, 1865.

Type species: Orthoceras complexum Barrande, 1856.

Orthoceracones and/or exogastric cyrtoceracones with circular, ovate, or somewhat elliptical cross-section, short camerae, and a relatively large, marginal, orthochoanitic siphuncle. Cavity of siphuncle partially restricted by secondary deposits arising from the connecting rings and assuming the form of thick-walled, apically truncated, adorally invaginated cones. Apical and apertural extremities of conch unknown.

The nomenclatural history and stratigraphic distribution of *Bathmoceras* were reviewed by Teichert in 1939 (p. 385—387) and by Ulrich, *et al.*, in 1944 (p. 129—130), and, since that time, only a few additions have been made to our knowledge of the genus. In the hundred years which have elapsed since Barrande described *Orthoceras complexum*, the type of *Bathmoceras*, only five additional species have been referred to the genus. Each of these, furthermore, is known from only one, or from just a few, incomplete individuals. Forms referable to *B. linnarssoni* Angelin are apparently the oldest known representatives of *Bathmoceras*, having been reported from the lower part of the Vaginatum limestone of Sweden (Holm, 1889)[1] and from the slightly younger Kunda limestone (B_{III}) of Estonia (Balaschov, 1953a,

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[1] In the original description of this species (Angelin & Lindström, 1880, p. 8) only the locality, Kinnekulle, Westrogothiae [= Västergötland] is given. Later (1888, p. 13) Lindström lists the species, together with others, from the Upper Gray Orthoceratite Limestone, now known to be equivalent to at least the upper part of the Schroeteri limestone. However, this was apparently a mistake, for Holm states (p. 271) that the type of *B. linnarssoni* comes from the Gray Vaginatum limestone, which, in present-day terminology, includes two units, the Expansus and Raniceps limestones. Holm also reports (1899, p. 272) an occurrence of the species in the Glauconitic Gray Vaginatum limestone of Öland.

p. 207; 1955a, p. 53, pl. 5, fig. 2). Both *B. complexum* (Barrande) and *B. praeposterum* Barrande (which is probably conspecific with *B. complexum*) come from the Šàrka beds at Wosek (near Rokycany) Czechoslovakia (Teichert, 1939, p. 386), which have long been considered to include strata equivalent to at least part of the Llanvirn of Great Britain. The only known specimen of *B. australe* Teichert was collected from a 74-foot fossiliferous band near the middle of the Larapintine Series in the Western Macdonell Ranges of Central Australia, which "band" Teichert (1939, p. 387) considers to correspond in age to " . . . the very late Skiddavian and Llanvirn of Great Britain." *Bathmoceras norvegicum*, n. sp., described below, comes from the Cephalopod shale at Helgøya (Nes—Hamar district), and these strata are generally considered to be equivalent in age to the upper part of the British Llandeilan.

Ulrich, *et al.* (1944, p. 130, pl. 8, fig. 3—8) referred to *Bathmoceras? tennesseense* the silicified internal molds of five small siphuncles, collected from the Chepultepec dolomite (probably Tremadoc in age) near Jefferson City, Tennessee. These authors very carefully point out, however, that these specimens are considerably older than the other known members of the genus, and unlike them in at least one particular. That is, the siphuncle apparently contains endocones, structures which are unknown in typical representatives of *Bathmoceras*. For these reasons, then, it does not seem advisable to continue the reference of Ulrich, *et al.*'s species to *Bathmoceras*, even tentatively. A specimen from the Sjdanovfjellet Series of Spitzbergen, described by Major (*in* Major & Winsnes, 1955, p. 37, pl. 4, fig. 4, 5) as *B.?* aff. *tennesseense* U.F.M.U., is likewise not a *Bathmoceras*. Its generic affinities are uncertain.

From the above discussion, it appears that *Bathmoceras* ranges from the upper part of the Arenig into the uppermost part of the Llandeilo, and has a geographic distribution which includes the Scando-Baltic, central Bohemian, and Central Australian provinces. As Teichert (1939, p. 387) has pointed out, it is unlikely that such highly specialized forms as these could have developed independently at about the same time in such widely separated regions; hence, there must have been reasonably free marine connections between these areas during late Lower, and early Middle Ordovician times.

Bathmoceras norvegicum Sweet, n. sp.

Plate 1, figures 5, 7; text-figure 1.

Type data: My knowledge of this new species is based on two incomplete internal molds, neither of which shows any of the internal features of the conch. The largest of these specimens, P.M.O. I 1527, is designated the holotype. The single paratype is housed in the State Museum of Natural History, Stockholm, where it is numbered 88002. Both specimens came from the Cephalopod shale on Helgøya, in the Nes—Hamar district.

Diagnosis: A slightly cyrtoceraconic species of *Bathmoceras*, in which the conch cross-section is ovate, the camerae are short, and the sutures sinuous, forming lateral lobes and dorsal and ventral saddles.

Descriptions: The holotype is an internal mold, 101.5 mm long, which represents 28 or 29 camerae of a slight cyrtoceraconic phragmocone. The maximum lateral and dorso-ventral diameters of the conch are essentially equal, but the cross-section is ovate rather than circular in shape, the dorsum being more narrowly rounded than the venter. At the adoral end of the twelfth camera, dorso-ventral and lateral diameters are 24 mm, whereas at the adoral end of the 28th camera (*see* text-fig. 1) they are 26 and 29 mm, respectively. The venter is gently but regularly convex throughout its length; the dorsum is concave. The camerae are short, 12 occurring in a length equivalent to the maximum lateral diameter of the conch. Sutures form rounded dorsal saddles, slight lateral lobes, and prominent ventral saddles, the crests of which project adorally for a distance equivalent to the length of one and a half camerae.

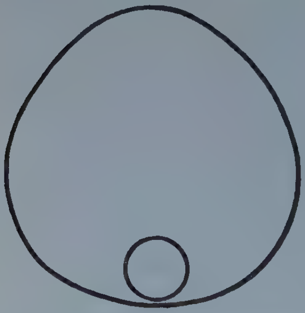

Fig. 1. *Bathmoceras norvegicum*, n. sp. Diagrammatic transverse section through the adoral end of the holotype, x1.

A small fragment of recrystallized test adheres to the adoral end of the right side of the holotype. The surface of this fragment is crossed by a series of growth-bands which appear to slope very slightly from venter to dorsum.

The siphuncle is ventral and marginal in position, and slightly less than 9 mm in diameter near the adoral end of the specimen. Its internal structure is not preserved, but, near the adapical end of the specimen, it has been etched by weathering in such a fashion that its principal features can be studied. The septal necks are rather short and orthochoanitic. The connecting rings are faintly concave externally, but their internal surfaces form a series of annuli which project inward and adorally for a distance equivalent to the length of about one camera.

The single paratype was collected by Prof. Gerhard Holm from the same horizon and locality as the holotype. It is 31 mm long and represents 11 camerae of the phragmocone. Like the holotype, it is ovate in cross-section, rather rapidly expanding, and slightly cyrtoceraconic. Sutures are well exposed laterally and ventrally. They form shallow, asymmetrical lateral lobes and broad, but fairly sharp-crested ventral saddles. The siphuncle is not preserved.

Remarks: Bathmoceras norvegicum, n. sp., differs from other species of the genus in that its section is ovate, rather than circular or depressed. Furthermore, it is slightly curved longitudinally, which sets it apart from other described species — with the possible exception of *B. australe* Teichert, which may also be a curved form.

Distribution: Bathmoceras norvegicum is known at present only from the Cephalopod shale at Helgøya, in the Nes—Hamar district, Norway.

Suborder Endoceratina Flower, 1950

[*nom. transl.* herein (*ex* Endoceratida Flower, 1950)].

FAMILY Endoceratidae Hyatt, 1883.

GENUS *Dideroceras* Flower, 1950.

Type species: Endoceras wahlenbergi Foord, 1887.

Dideroceras was erected by Flower (in Flower & Kummel, 1950, p. 609) for endoceroids " . . . unique in having septal necks which extend apicad for the length of one and a half to two camerae, with connecting rings." Recently, the same author (Flower, 1955a, p. 368) has given a somewhat more complete diagnosis, in which the genus is conceived to include " . . . slender endoceroids with rather deep camerae in proportion to the shell diameter. Siphuncle ventral, septal necks extending for the length of two camerae, rarely one and a half. Endocones simple, their termination subcentral. Blades have not been observed. Apical ends are believed to belong to the *Nanno* type, but further confirmation is required."

The latter diagnosis implies that, since 1950, Flower has studied material in addition to that available to either Foord or Holm (1895, p. 9—17, pl. (1), fig. 1—8), for both their illustrations of *Endoceras wahlenbergi*, upon which our concept of *Dideroceras* must rest, show septal necks which extend apicad for only one and a half camerae. In addition to *Dideroceras*, unusually long, or macrochoanitic septal necks are apparently found in *Chisiloceras* Gortani (which, however, has a central rather than a ventral siphuncle), in *Kotoceras* Kobayashi (which is a depressed endoceroid with specialized endocones), and in *Hudsonoceras* Flower (which shows a peculiar ventral disposition of endosiphuncular deposits and is referred, for that reason, to the Manchuroceratidae rather than to the Endoceratidae). Specimens from the Middle Ordovician of south Korea, referred by Kobayashi (1934, p. 387, pl. 13, fig. 4—5: p. 388, pl. 13, fig. 6; pl. 14, fig. 4) to *Vaginoceras neichianense* Yu and *V.* cf. *reedi* Yu, have long septal necks, extending, at least adapically, for a distance of about one and a half camerae. These probably belong in *Dideroceras*. However, the same appears to be true of Kobayashi's (1934, p. 386, pl. 10, fig. 1—5) *Cyclendoceras orientale*, which, in addition to closely spaced surficial annuli, also has septal necks that appear to be prolonged adapically for one and a half camerae. Macrochoanitic septal necks do not, then, seem to be particularly rare, although (as suggested by the chronology) they may well be a primitive structure.

According to Flower (1955a, p. 368), *Dideroceras* is known to occur in the " . . . upper red and grey Orthoceras limestone of Europe and Asia." Holm reports *Endoceras wahlenbergi* from the glauconitic gray Vaginatum limestone of Öland and from the red Vaginatum limestone of Östergötland, and Harrington & Leanza (1957, p. 35), on the authority of Cecioni, report a specifically indeterminate *Dideroceras* from the *Hoekaspis schlagentweiti* zone (lower Llanvirnian) in the Rio Capillas district of Argentina. In the Oslo Region, the genus is known at present only from the lower part of the Ogygiocaris Series

($4a\alpha_{1-2}$) but it may eventually be found to occur in the subjacent Asaphus Series, the cephalopod fauna of which has not yet been studied in detail. In this connection, it should perhaps be mentioned that Foord (1888, p. 140) reports that there are specimens of *D. wahlenbergi* from three Norwegian localities (Fossum, River Glommen, and Drøbak) in the collections of the British Museum. Those from the latter two localities were certainly collected from drift boulders, but at Fossum, near the southwestern corner of the Oslo Region, an essentially complete Ordovician section is exposed. It is probable, then, that the specimens available to Foord also came from some part of the Ogygiocaris Series.

Dideroceras wahlenbergi (Foord).

Plate 2, figure 9; Plate 21, figure 3; text-figure 2A—B.

1887. *Endoceras Wahlenbergi* FOORD, Ann. and Mag. Nat. Hist., ser. 5, v. 20, p. 393, fig. 1a—e.
1888. *Endoceras Wahlenbergi* FOORD, Catalogue of the Fossil Cephalopoda in the British Museum, pt. 1, Nautiloidea, p. 136—140, fig. 11, 13—14.
1895. *Endoceras Wahlenbergi* HOLM, Geol. Fören. i Stockholm, Förh., bd. 17, p. 9—17, pl. 1, fig. 1—8.
1950. *Dideroceras wahlenbergi* FLOWER, *in* Flower & Kummel, Jour. Paleontology, v. 24, p. 609.

Material: Ten pyritized internal molds, all incomplete. These are stored in the Paleontological Museum, Oslo, where they are numbered I 0200, I 0202—3, I 0205, I 11341–2, 64316—18, 64320, 3585 (= I 0244), 69260, 69261.

Description: The most nearly complete of the several Norwegian specimens at hand is illustrated in figure 9 on plate 2. This specimen is a pyritized internal mold, 310 mm long, which represents about 32 camerae of the phragmocone. The specimen is crushed, but at its adoral end the conch has a circumference of about 125 mm, which indicates an original diameter of ca. 40 mm (if the conch is assumed to have been essentially circular in cross-section as are other, smaller fragments of the same species). Seventy-three mm apicad of the adoral end, the reconstructed dorso-ventral diameter is 35 mm, which indicates that the conch originally enlarged very slowly (about 1:15) and had an apical angle of about 4°. The siphuncle is ventral and nearly

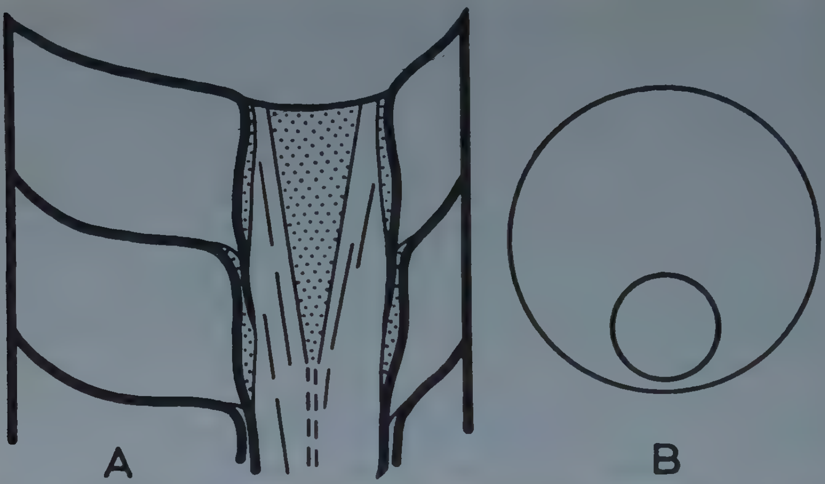

Fig. 2. *Dideroceras wahlenbergi* (Foord). (A) Diagrammatic oblique section through the siphuncle, x3. (B) Reconstructed adoral cross-section of the specimen shown in figure 3, Plate 21, x1.

marginal in position and, near the adoral end of the specimen, its diameter is 13 mm, or about one-third that of the conch.

Text-figure 2A, drawn from an oblique section through the siphuncle of a small specimen (*see* figure 3, Plate 21), shows that the septa have a concavity equivalent to about half the length of a camera. The siphuncle is composed of macrochoanitic septal necks which extend apicad for a distance of one and a half camerae, and connecting rings whose length is equivalent to that of the septal necks. The necks are convex outward in their mid-portions, concave where they overlap the next adapical neck, and slightly convex outward at their pointed adapical extremities. The connecting rings begin at the septal foramen, between the neck of that septum and the invaginated neck of the next adoral septum. They are thin for the length of half a camera, thicken to the width of the invaginated neck at its adapical end, then thin gradually adapically to form only a "coating" on the inner side of the distal end of the invaginated neck. This variation in thickness serves to "smooth-out" the inner surface of the siphuncle so that only broad annulations show on the external surfaces of the siphuncular fillings.

The ectosiphuncular sheath is occupied by secondary organic deposits in the form of endocones, built up as a series of apparently intergrading conical lamellae, the apices of which lie in the siphuncular mid-line. From measurements and reconstructions involving several specimens, it appears that these deposits filled the siphuncle for a distance of at least 180 mm orad from the apical end. Slight differences in color within the endosiphuncular deposits suggest the presence of a thin, straight, subcentral tube; but no other structures have been detected.

Remarks: All of the specimens at hand, although distorted to a greater or lesser degree, compare favorably with the ones upon which Foord based his concept of *Endoceras wahlenbergi*. It might be noted that Foord's specimens enlarge at a somewhat greater apical angle (5° rather than 4°) than do those I am studying and, in at least one of his forms (1888, p. 131, fig. 13) the mid-siphuncular tube is sinuous, rather than straight.

It should perhaps be pointed out that, although Flower (1955a, p. 368) reports that blades have not been observed in the endosiphuncular deposits of *Endoceras wahlenbergi*, Holm (1895, p. 9—17, pl. 1, fig. 2,6) mentions and clearly illustrates these structures in a specimen he referred to that species from the glauconitic gray Vaginatum limestone of Öland. There are two blades illustrated which, together with the illustrated lachrymiform cross-section of the siphuncle, give the endosiphuncular deposits a pronounced asymmetry. It is possible, of course, that these structures serve to indicate that Holm's specimens were specifically distinct from Foord's. There is no reason at present to advocate such a distinction, however, for Foord's notes do not include any very clear discussion of the endosiphuncular structures of the types of *Endoceras wahlenbergi*, so it is not known what latitude should be allowed the species at present.

Foord refers to *Endoceras wahlenbergi* a number of forms described by others as *Orthoceras*, *Orthoceratites*, or *Endoceras duplex* Wahlenberg, but his reasons for doing so are not very clear. Most of these forms were apparently associated with *E. wahlenbergi* on the basis of external similarities, for the illustrations cited fail, for the most part, to give any suggestion of the siphuncular structure. Fot this reason, Foord's synonymy is not repeated above; a proper disposal of forms included in it would require an extensive restudy of widely scattered type material, a project which is beyond the scope of the present work.

Distribution: In Norway, this species appears to be restricted to the Upper Didymograptus shale ($4a\alpha_{1-2}$). Representatives of it have been collected from that horizon at Huk and Killingstad, Bygdøy; and from exposure on Finnmarksgate, Tøyen, all in the Oslo—Asker district.

GENUS *Endoceras* Hall, 1844.

Endoceras spp.

Plate 3, figures 10, 11.

In the collections I am studying, there are a number of fragmentary, but probably congeneric endoceroids which I am unable to identify specifically. All of these forms, however, appear to be holochoanitic and they are being referred, for that reason, to *Endoceras* (*s. l.*) even though the structure of the endosiphuncular deposits can not be determined in any of them. Two of the more nearly complete specimens are illustrated, and the following descriptions of them are included, largely for the sake of completeness.

The larger of the two illustrated specimens is an internal mold, 116 mm long, which represents about 8 camerae of the phragmocone. This segment expands rather slowly (ca. 1:6), is slightly depressed in cross-section, and is gently but regularly curved longitudinally. The siphuncle is large (ca. three-sevenths the conch diameter), marginal, and located on the convex side of the conch. About 5 camerae occur in a length equivalent to the lateral diameter of the conch. Sutures are straight and directly transverse. The siphuncular wall is composed of holochoanitic septal necks which extend apicad for the length of one camera. No connecting rings have been observed; they may have been destroyed by recrystallization or solution. The endosiphuncle is completely filled with dark gray, fine-grained limestone, which suggests that endocones were not originally developed this far orad in the conch.

The smaller of the two illustrated specimens is 85 mm long, and represents 7 camerae of a phragmocone which is slightly curved longitudinally and essentially circular in section, having a diameter of 56 mm. The septa are shallow, saucer-shaped, and join the walls of the conch to form simple, straight sutures, which are directly transverse to the axis of the conch. The siphuncle is circular in section, ventral in position, and 22 mm in diameter at the adapical end of the conch. It is composed of holochoanitic septal necks which extend apically for a length of one camera. In their adoral halves, the septal necks are distinctly concave in vertical outline, but in their adapical portions they expand slightly within the camerae. Connecting rings, if present, are indistinguishable. No endosiphuncular deposits are recognizable, presumably the fragment represents a portion of the conch orad of the youngest endocones.

Remarks: Endoceroid taxonomy has been so refined in recent years that it is difficult to make proper generic (let alone specific) disposition of fragmentary material which does not preserve the frequently elaborate endosiphuncular structures. Indeed, the scope of the genus *Endoceras* has been so restricted (Flower, 1955a, p. 340—342) that it is probable that only a few of the vast number of previously described species can still be referred to it. The specimens at hand are all slightly curved longitudinally and exogastrically. Such curvature has not previously been reported in the endoceroids, but it is probably not a primary feature in the Norwegian forms. That is, most of the specimens I have observed in place are oriented with the heavy, siphuncular side down and it would be expected that any post-mortem deformation of the shell due to diagenetic or tectonic compaction of the sediments surrounding it would result in a depression of the center of the conch and a bowing of its extremities. Radial, open fractures transecting the siphuncular fillings tend to support the view that this curvature is secondary rather than primary.

Distribution: The illustrated specimens (P.M.O. I 1881 and 61067) come from the Ampyx limestone at Høvik, Bærum, and from the Upper Chasmops limestone on Bjerkøya, both localities in the Oslo—Asker district. Other specimens, which are too poorly preserved or incomplete to merit description or illustration, occur in collections from the Cephalopod shale on Helgøya (Nes—Hamar district), from 4bα at Gomnes—Rud (Ringerike district), and from 4bδ on Gåsøya (Oslo—Asker district.)

Genus *Vaginoceras* Hyatt, 1884.

Vaginoceras sp.

Plate 1, figure 4; text-figure 3A—B.

Material: Four specimens (R.M. MO 87972; P.M.O. 69262, I 1568—36929—36928 (one specimen), 69263,) all fragmentary, partially testiferous internal molds. All four specimens are from the Cephalopod shale on Helgøya (Nes—Hamar district).

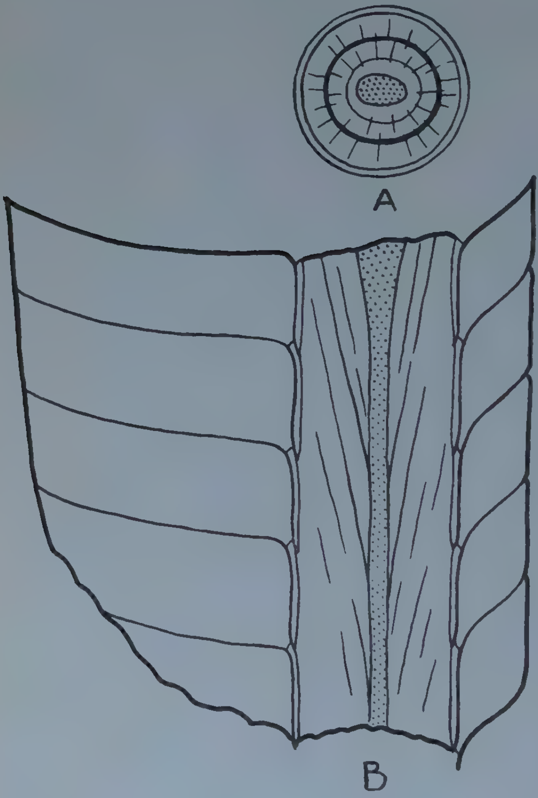

Fig. 3. *Vaginoceras* sp. (A) Diagrammatic cross-section through the adoral end of the siphuncle, x2. (B) Schematic longitudinal section through the siphuncle, x2, Both diagrams prepared from the specimen shown in figure 4, Plate 1.

Descriptions: Although small and somewhat less complete externally than the other specimens, the illustrated individual exhibits the diagnostic internal features of the conch and hence merits a more detailed description than do the rest. The specimen to which I refer is an incomplete internal mold, representing 5 camerae of a slightly depressed phragmocone with dorso-ventral and lateral diameters of 34 and 38 mm, respectively, at its adoral end. The camerae are fairly short, about 6 occurring in a length equivalent to the maximum lateral diameter of the conch. As a result of the conch depression, the sutures form slight dorsal and ventral lobes with broad intervening lateral saddles.

The siphuncle is large and essentially circular in section. At the adoral end of the specimen it has a diameter of 13 mm, and is located only 3 mm from the ventral wall of the conch. As shown in text-figure 3B, the ectosiphuncle is composed of holochoanitic septal necks which are perfectly straight for most of their length but slightly incurved at their distal ends. These necks, which are only one camera long, merge distally into thick connecting rings which begin in the septal foramen and extend apicad on the inner side of the septal neck to the distal end of the next septal neck. As a result of this, the inner side of the ectosiphuncle is quite smooth. With the exception of a thin, subcentral tube, the endosiphuncle is filled by thick calcareous endocones, formed of cone-shaped laminae, the surfaces of which meet the central tube at an angle of a little less than 20°. In cross-section, the central tube and the tip of the speiss are subcuneate in shape (*see* text-figure 3A), being laterally compressed and more narrowly rounded ventrally than dorsally. No blades like those reported in other species of *Vaginoceras* are discernible, but such a structure may be represented by a thin, dark, radial line in the ventral part of the siphuncular deposits. It should be pointed out, however, that the siphuncular deposits have been recrystallized and now consist of radially arranged calcite crystals. These recrystallized deposits, therefore, fracture readily in a radial pattern and are transected by numerous discontinuous, thread-like breaks. It is possible, consequently, that the blade-like structure noted above may be nothing more than a discoloration along one of these fractures.

No cameral deposits occur in the specimen at hand; the dorsal shell wall has been completely destroyed, and the chambers filled with dark gray limestone. However, a series of faint, longitudinal ridges occurs on the ventral side of the internal mold. Such ridges have been interpreted to represent "incipient cameral deposits"

(Flower, 1946, p. 50; 1955d, p. 100) in other genera, and they may have the same explanation in the specimen at hand It is possible on the other hand, that they were formed during the growth of the animal in association with the forward migration of the retractor musculature.

In general shape and proportions, the remaining three representatives of *Vaginoceras* in collections at hand are similar to the small specimen just described. All of them, however, represent considerably larger, and therefore younger parts of the conch, and in none of them are any traces of the endosiphuncular deposits preserved. The small fragments of recrystallized test which adhere to two of these forms are smooth-surfaced and marked only by a series of very fine, closely spaced growth-lines.

Remarks: Vaginoceras is closely similar to *Endoceras*, and the two names have generally been regarded as synonyms. Flower (1955a, p. 340—342, 348—350), however, has recently restudied the types of both genera and his emended diagnoses of them indicate that, although very closely related, the two are probably distinct. That is, the "endosiphotube" of *Vaginoceras* is compressed, cuneate in cross-section, and supplemented by dorsal and ventral blades. That of *Endoceras* is subtriangular and supported by three radial blades which are ventro-lateral and dorsal in position. In that the tube of the Norwegian specimen just described is compressed and subcuneate in cross-section, it resembles *Vaginoceras*. Furthermore, the numerous thin, strongly inclined lamellae in the endosiphuncular deposits and the smooth-surfaced ectosiphuncle are apparently also characteristic of that genus as Flower has redefined it.

Hyatt apparently had misconceptions concerning the siphuncular structure of *Orthoceras multitubulatum* Hall when he proposed the name *Vaginoceras* for it, hence it is not surprising to find that a variety of species fitting Hyatt's description, but probably not congeneric with Hall's species have been referred to *Vaginoceras*. As Flower (1955a, p. 348—350) has pointed out, however, only a few of these can still be retained in the genus with certainty, hence it is somewhat difficult to determine its stratigraphic range. Insofar as I can determine, valid species of *Vaginoceras* are known only from North America and Greenland, where they occur in strata of Wilderness (= Black River) age, that is, in rocks which are somewhat younger than the Cephalopod shale of the Oslo Region.

Distribution: In Norway, *Vaginoceras* occurs in the Cephalopod shale on Helgøya (Nes—Hamar district). Two poorly preserved specimens which are externally somewhat similar to the Cephalopod shale forms occur in collections from the Ampyx limestone in the Oslo—Asker district. These specimens may represent *Vaginoceras*, but can not be assigned to that genus with certainty.

GENUS *Cyrtendoceras* Remelé, 1886.

Cyrtendoceras, n. sp.

Plate 10, figure 6; text-figure 4A—B.

Material: A single, partially testiferous internal mold (P.M.O. I 1523) from the Cephalopod shale at Helgøya (Nes—Hamar district.)

Description: A partially testiferous internal mold, 83 mm long, which represents at least 6 adoral camerae of the phragmocone and an essentially complete body chamber. The conch fragment is curved longitudinally and compressed laterally, having estimated dorso-ventral and lateral diameters of 36 mm and 30 mm, respectively, at its adapical end. At the apertural margin, a portion of which is preserved laterally, the lateral and dorso-ventral diameters are about 42 and 45 mm. Both the venter and dorsum are curved, the venter (or siphuncular side) being concave, the dorsum convex. The sides are straight adapically, but near the apertural margin they curve inward slightly, indicating that the aperture was slightly constricted. A part of the peristome is preserved on the right side of the conch. It is straight and slopes slightly apicad from dorsum to venter. The camerae are short, about 9 occurring in a length equivalent to the dorso-ventral diameter of the conch. Apparently the septa are only slightly concave. Due to compression, the sutures form slight lateral lobes and low, broad ventral and dorsal saddles.

The surfaces of both the internal mold and the large areas of test which adhere to it are marked by a series of transverse annulations. Those of the test are low, distinct, parallel to the sutures, and closely spaced, one occurring near the adapical end of each camera. The

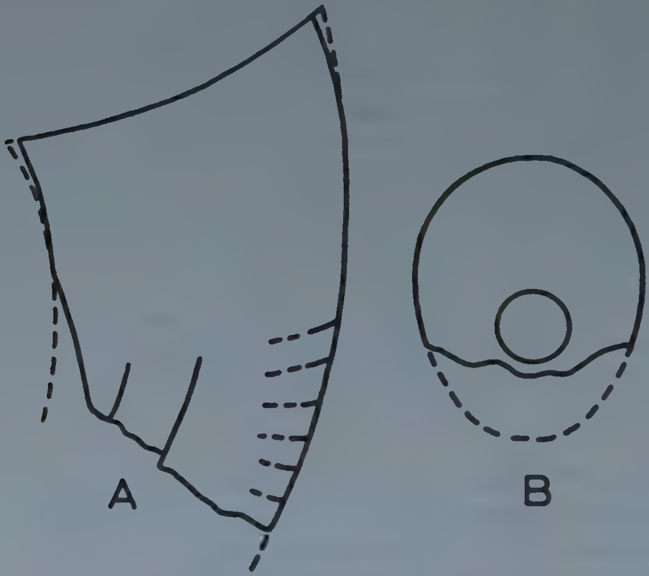

Fig. 4. *Cyrtendoceras*, n. sp. Reconstructed, somewhat schematic longitudinal (A) and transverse (B) sections through the specimen shown in figure 7, Plate 10. Both diagrams x1.

annulations shown on the internal mold, however, are faint, low, and rather widely spaced, their crests being about 12 mm apart.

Text-figure 4A is a diagrammatic view of a longitudinal dorsoventral section through the specimen. The septa are preserved only near the dorsal margin of the conch, and the position and size, but not the structure of the siphuncle are indicated in the adapical part of the section by two thick, parallel, curving lines of recrystallized calcite. These structures, together with the features shown in an adapical cross-section of the conch (text-figure 4B) indicate that the siphuncle was circular in section, 9 mm in diameter, and located between the center and the concave margin of the conch.

Remarks: Even though the internal structures of this specimen have been largely destroyed, it is so similar to previously described species of *Cyrtendoceras* that it is being assigned to that genus without question. With only a few exceptions, species of *Cyrtendoceras* are similar in that they are compressed, rather strongly curved, closely camerated, and externally annulated to a greater or lesser degree. The specimen at hand has a siphuncle which is located somewhat farther from the concave (ventral?) side than is apparently typical, and its body chamber is slightly contracted aperturally. For these reasons, it is suspected that it represents a previously undescribed species. No name is being proposed for it, however, for it is felt that such an incomplete specimen would serve as a very poor holotype.

The name *Cyrtendoceras* was first published ([Remelé] 1886, p. 338) in the third-person account of a paper presented by Adolf Remelé before a scientific meeting in Berlin, and, although a brief description of the genus was given in that report, no species are mentioned. There is, therefore, some question as to whether or not the name should be ascribed to Remelé, or to Patrunkey (1926, p. 127) who was the first to refer a valid species to it. Teichert & Glenister (1954, p. 65—66) point out, quite correctly, that *Endoceras* (*Cyrtocerina*) *hircus* Holm, referred to *Cyrtendoceras* by Patrunkey in 1926, must be considered the type of *Cyrtendoceras*. However, they are of the opinion that Patrunkey is also the author of the generic name. I am inclined to believe that the name *Cyrtendoceras* was clearly made available by Remelé in 1886 for " ... all the species of the world which would come under the generic description as originally published ..." (Summary of Opinion 46, I. C. Z. N.) and he should, therefore, be cited as its author. Foerste's (1932b, p. 165) proposal of the name *Cyrtendoceras remelei* for the specimen upon which Remelé apparently based his concept of *Cyrtendoceras* does not affect the status of *C. hircus* (Holm) as its type.

In addition to the unnamed group probably represented by the specimen at hand, three species of *Cyrtendoceras* are known from the Scando-Baltic province. All of these come from rocks of early Middle Ordovician age; that is, from the Aseri limestone of Estonia, the somewhat younger Schroeteri limestone of Sweden, and from the Cephalopod shale of Norway. *C. estoniense* Foerste, from the Lower Ordovician Kunda limestone of Estonia, differs greatly from other species of *Cyrtendoceras*, and probably belongs in some other genus, perhaps in *Campendoceras* Teichert & Glenister. *C. carnegiei* Teichert & Glenister, from an Upper Canadian horizon in the Emanuel limestone of Northwestern Australia, is, indeed, similar to the Baltic species described by Holm (1895) and Foerste (1932b, p. 165—170, pl. 1, fig. 1,2; pl. 2, fig. 2). However, Flower (1955a, p. 338) believes the types of this species to be the adapical portions of a piloceroid, which is possibly the case.

Distribution: The only representative of *Cyrtendoceras* known from the Oslo Region, comes from the Cephalopod shale exposed at the south tip of Helgøya, in the Nes—Hamar district.

Suborder Actinocertina Flower, 1950

[*nom. transl.* herein (*ex* Actinoceratida Flower, 1950)].

FAMILY Armenoceratidae Foerste & Teichert, 1930.

GENUS *Nybyoceras* Troedsson, 1926.

Nybyoceras holmi Sweet, n. sp.

Plate 1, figure 1; Plate 21, figure 4; text-figure 5A—B.

Name: This new species is named in honor of the late Professor Gerhard Holm, of Stockholm, who collected the holotype.

Type data: Holotype (R.M. MO 150035—36) a partially testiferous internal mold, the adapical 6 camerae of which have been sectioned longitudinally so as to expose the siphuncle.

Material: In addition to the holotype, Professor Holm's collections from Helgøya, in Norway, contain the internal mold of a fragmentary body chamber which also appears to belong in *Nybyoceras holmi*, n. sp. This specimen is also housed at the State Museum of Natural History in Stockholm, where it is numbered MO 150037.

Diagnosis: A species of *Nybyoceras* which agrees with the type species of the genus in conformation of the ectosiphuncle, but differs from it in that the conch is depressed and the endosiphuncular annuli appear to be more elaborately developed ventrally than dorsally.

Descriptions: The holotype is a partially testiferous internal mold, 50 mm long, of part of a straight phragmocone which is subelliptical in cross-section with dorso-ventral and lateral diameters which increase from 13 and 16 mm adapically to 21 and 24 mm near the adoral end. This indicates an apical angle of about 12° between the sides and 18° between the dorsum and the venter. Nine camerae are preserved.

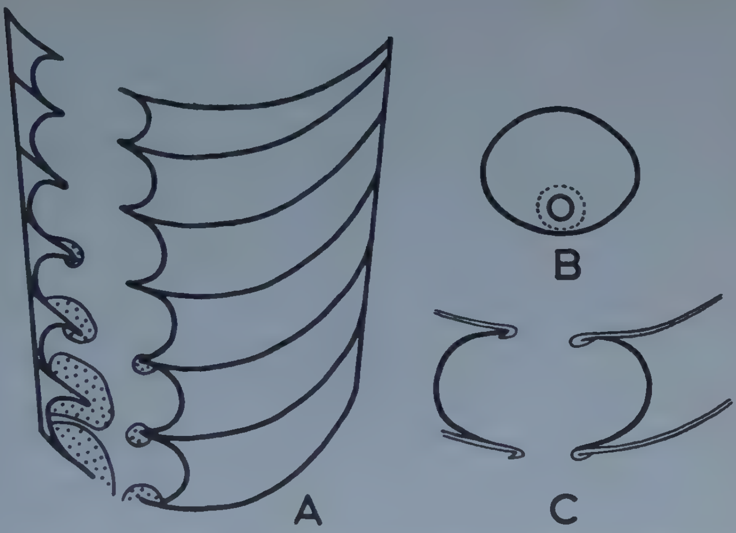

Fig. 5. *Nybyoceras holmi*, n. sp. Diagrammatic longitudinal and transverse sections of the holotype, x3 and x1, and an enlarged, schematic view of one segment of the siphuncle.

The septa have a concavity equivalent to the length of one camera, and their junction with the walls of the conch produces sutures which form broad dorsal and ventral lobes and somewhat narrower lateral saddles. The test preserved at the adoral end of the specimen shows a series of very faint, fine growth-lines which are straight and directly transverse to the axis of the conch dorsally and laterally, but which form slight sinuses ventrally.

Text-figure 5A is a diagram of a slightly oblique dorso-ventral cross-section through the adapical 6 chambers of the specimen (*see* also figure 4, Plate 21). From this figure it can be seen that the siphuncle is large, close to the venter, and composed of segments which expand broadly within the camerae. Furthermore, it decreases somewhat in size adorally, by an amount greater than can be attributed to the slight obliquity of the section. The septal necks are abruptly recurved and are short and recumbent dorsally but somewhat longer and not in contact with the adapical surface of the septum ventrally. In addition to this, the septa become somewhat convex adorally immediately adjacent to the dorsal side of the siphuncle. The connecting rings are thin, and broadly adnate to the adapical surface of the succeeding septum. In the adoral part of the ventral side, and in the adapical portion of the dorsal side, the rings are in contact with the septal surface for only a short distance. Annulosiphonate deposits occur in the adapical 4 camerae of the holotype. These take the form of simple annuli in the septal foramen and adjacent parts of the camerae, but appear to be more heavily developed ventrally than dorsally. Furthermore, the sequence preserved suggests that, on the ventral side, the deposits tended to grow more rapidly in an adoral direction, whereas those on the dorsal side are prolonged most noticeably adapically. In part of the phragmocone preserved, the central "tube" is incompletely formed, and only one radial canal is preserved. This canal is arcuate in cross-section, with the convex side of the arc adoral. No perispatium is preserved, and the intimate relation between deposits and connecting ring suggests that no structure of this nature existed originally. Thin episeptal deposits occur in the dorsal portion of the camerae. Recrystallization of these deposits prevents a determination of their structure.

The single paratype represents an adorally incomplete, partially testiferous internal mold of a detached body chamber, 43 mm long, which is depressed in cross-section and expands at a rate similar to that of the holotype.

Remarks: The depressed conch of this species, together with the ventral concentration of endosiphuncular deposits is sufficient to set it apart from other known species of *Nybyoceras*. The shape of the ectosiphuncle, however, is closely similar to that of *N. bekkeri* (Troedsson), the type species, as is the relationship between septal necks and connecting rings. It should also be noted that the siphuncle appears to decrease in diameter adorally, a feature seemingly characteristic of *Nybyoceras*.

Distribution: The only known representatives of *Nybyoceras holmi* are from the Cephalopod shale at Hovindsholm, Helgøya in the Nes—Hamar district, Norway.

Nybyoceras sp.

Plate 5, figures 4, 7.

Material: Two incomplete specimens (P.M.O., I 1466, I 1475) from the Cephalopod shale at Helgøya (Nes—Hamar district) belong in *Nybyoceras*, and may be conspecific with *N. holmi*, n. sp. They are being described separately, however, because they are so poorly preserved that specific identification is not possible.

Descriptions: The specimen represented by figure 7 on Plate 5 is 92 mm long. The adapical 52 mm consits of about 12 camerae of the phragmocone which have been partially recrystallized, and weathered in such a fashion that a natural lateral section, exposing the siphuncle, is formed. The adoral 40 mm of the specimen is a hollow internal mold, from which weathering has removed all of the internal structures of the conch. Although this specimen is quite incomplete, it appears that it represents a rather gradually expanding conch of slightly depressed cross-section, the siphuncle of which is ventral in position, but apparently not quite marginal. The septal necks are cyrtochoanitic; the connecting rings expand rather widely within the camerae, and appear to be adnate adapically but not adorally. The siphuncular segments are now filled with light-colored, coarsely crystalline calcite which suggests that they were originally occupied by annulosiphonate deposits which were recrystallized during fossilization of the shell.

The specimen shown in figure 4 on Plate 5 is 49 mm long and consists of an internal mold of 7 camerae of a narrow, slowly expanding phragmocone which is somewhat depressed in cross-section. The camerae are short and shallow, and the sutures, which are essentially straight dorsally and laterally, form slight ventral lobes. The surface of the specimen is marked by a series of fine, irregular longitudinal lines, the crests of which are about 1 mm apart. The siphuncle is essentially circular and about 4 mm in diameter where it passes through the septum, and its ventral side is located 4.8 mm from the ventral wall of the conch at the specimen's adoral end. Its segments become somewhat smaller in diameter adorally. Internally, the siphuncle is composed of strongly recurved (but not recumbent) septal necks, moderately expanded connecting rings, and secondary annulosiphonate deposits, the detailed structure of which has been destroyed by recrystallization.

Distribution: Both of the specimens described above come from an exposure of the Cephalopod shale at Hovindsholm, Helgøya, in the Nes—Hamar district, Norway.

FAMILY Ormoceratidae Saemann, 1852.

GENUS *Ormoceras* Stokes, 1838.

Ormoceras kiaeri Sweet, n. sp.

Plate 20, figures 1, 2; text-figure 6A—D.

Name: The specific name, *kiaeri*, is proposed in honor of the late Professor Johan Kiær, who was for many years Professor of Historical Geology and Paleontology at the University of Oslo.

Type data: The holotype, P.M.O. I 1602, is a natural longitudinal section of a fragmentary phragmocone which has been polished to bring out details in the internal structures. It was collected from the Mjøsa limestone near Bergvik, Helgøya (Nes—Hamar district) by Professor Kiær.

Material: In addition to the holotype, the collections of the Paleontological Museum in Oslo contain six similarly preserved specimens, all from the Mjøsa limestone in the Nes—Hamar, and Ringsaker districts, which are being referred to this new species without question. These specimens are numbered P.M.O. 69264, 69265, 56901, 56902, 64980, 64991.

Diagnosis: A depressed, closely camerated species of *Ormoceras*, with a large, subcentral siphuncle.

Descriptions: The holotype is an internal mold, 61 mm long, which represents 20 camerae of the phragmocone and has been weathered in such a fashion as to present a natural longitudinal section through the siphuncle. In a length of 40 mm, the conch expands from diameters of 20 mm to 27 mm, suggesting an apical angle of between 8° and 9°. Reconstructions suggest that the original cross-section must have been either considerably depressed (as shown in text-figure 6D) with a subcentral siphuncle, or subcircular with a markedly eccentric siphuncle (as shown in text-figure 6C). Several other representatives

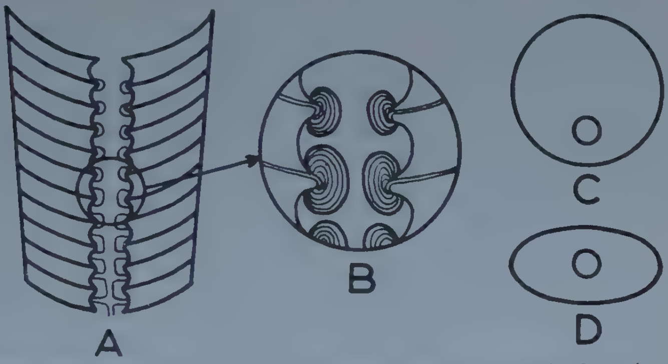

Fig. 6. *Ormoceras kiaeri*, n. sp. (A, B) Diagrammatic longitudinal sections through the holotype, B being an enlargement, x3, of a portion of A, to show the structure of the endosiphuncular deposits. (C, D) Reconstructions of the cross-section of the holotype according to two postulated positions for the siphuncle.

are depressed and have a subcentral siphuncle, hence it is assumed that the same was originally true of the holotype and that text-figure 6D represents its true cross-sectional shape. The camerae are short; the dividing septa are regularly saucer-shaped and have an adapical convexity equivalent in length to about 1/3 camera. The siphuncle is cyrtochoanitic, being composed of recurved (but not recumbent) septal necks and broadly expanded connecting rings. At the septal foramen the siphuncle has a width equivalent to about one-seventh the conch diameter, but near cameral mid-length, it expands to a diameter of a little less than a fourth that of the conch. Simple annulosiphonate deposits occur within the ectosiphuncle and, as is typical of the actinoceratinids, they are more advanced adapically than adorally. As shown in text-figure 6B (and in figure 2, Plate 20), these deposits consist of annuli in the septal foramina which show internal laminae indicating that they grew both adapically and adorally by circumferential accretion. In the adapical chambers, the deposits of adjacent camerae approach each other so that only a narrow space separates them near cameral mid-length and the siphuncular opening is constricted to a narrow, straight, subcentral tube. No perispatium is visible adapically, but such a space appears to be present between annuli and connecting rings adorally.

The camerae of the holotype are occupied by thin episeptal deposits which apparently are continuous around the complete circumference of the conch. These deposits, which are thicker adapically than adorally, developed first in the angle between the free portion of the septum and the wall of the conch, later spreading toward the siphuncle along the adoral face of the septum, and adorally along the cameral walls. About half-way between the conch wall and the siphuncle, the deposits are abruptly terminated.

A median dorso-ventral section through a larger and somewhat more completely preserved specimen is shown by figure 1 on Plate 20. This specimen is 48 mm long, and represents 10 camerae of a somewhat depressed phragmocone (dorso-ventral and lateral diameters at the adapical end, 23 and 28 mm, respectively) with a large, subcentral siphuncle. The configuration of the ectosiphuncle is exactly like that of the holotype, but the specimen apparently preserves none of the annulosiphonate deposits.

Remarks: The specimens at hand differ from *Ormoceras hadelandicum* (Strand) in that the septal necks are not recumbent and the conch is somewhat depressed (rather than circular). *O. kiaeri* is also similar to and probably closed related to *O. tyriense* (Strand) but that species may be cyrtoceraconic, and the septal necks appear to be recumbent. In addition, the siphuncle of *O. tyriense* is submarginal in position rather than subcentral as in *O. kiaeri*.

Distribution: O. kiaeri, n. sp., is known from the Mjøsa limestone in the Nes—Hamar district, where representatives of it have been collected at Bergvika, Helgøya. Other specimens of the same species were collected at a locality on the east side of Brummundal, in the Ringsaker district.

FAMILY Lambeoceratidae Flower, 1957.

GENUS *Hoeloceras* Sweet, n. gen.

Name: The genus is named in honor of Mr. Jacob Hoel, proprietor of the farm Hovindsholm on Helgøya.

Type species: Hoeloceras helgoeyense Sweet, n. sp.

Diagnosis: Depressed (but not flattened) lambeoceratids, elliptical in cross-section and with sutures bearing dorsal and ventral lobes

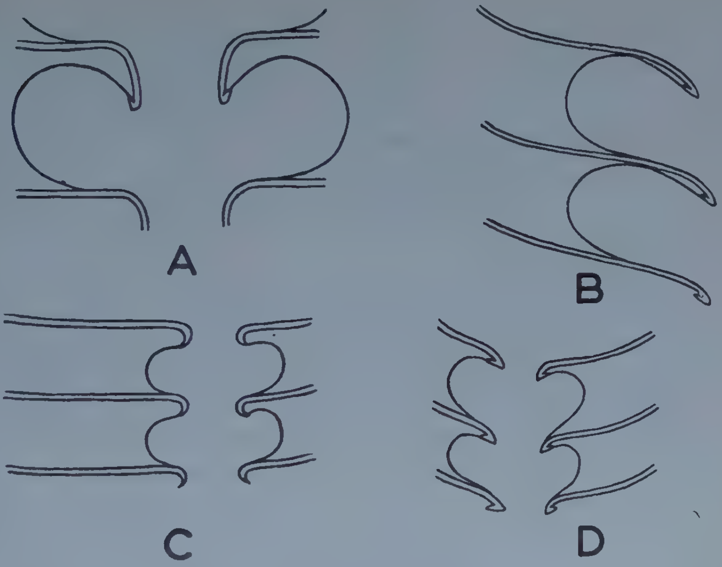

Fig. 7. Schematic representations of the ectosiphuncles of (A) *Lambeoceras*, (B) *Gonioceras*, (C) *Actinoceras*, and (D) *Hoeloceras*, n. gen. (A) and (B) after Teichert, 1934.

and lateral saddles. Septa curve apicad near the septal foramen; the septal neck is short, acutely recurved, and recumbent. Connecting rings broadly expanded in each camera and adnate adapically but not adorally. Endosiphuncular deposits typically actinoceroid.

Remarks: Hoeloceras is clearly related to both *Gonioceras* and *Lambeoceras*, and may be intermediate between these genera and *Actinoceras*. The genus differs from *Gonioceras* in that the conch is not strongly flattened, the lateral margins are not angular, and the sutures are not recurved ventro-, and dorsolaterally. The siphuncular structure is quite similar to *Gonioceras*, but in that genus the connecting rings are more broadly expanded within each camera and are adnate to the bounding septa both adapically and adorally. In conch shape, *Hoeloceras* is more nearly like *Lambeoceras*, but the sutures of *Lambeoceras* show angular lateral saddles and occasionally a slight lateral reversal in curvature. A comparison of the ectosiphuncular structure, however, serves to distinguish the two genera. That is, in *Lambeoceras*, the septa bend abruptly apicad at the septal foramen in a pseudo-orthochoanitic fashion and it is only at the extreme adapical end of these funnel-like processes that short, recumbent septal necks are developed. The septal neck of *Actinoceras* is a simple, cyrtochoanitic structure and is not preceded adorally by any appreciable deflection of the septa. For comparative purposes, outlines of the siphuncular segments of *Actinoceras*, *Gonioceras*, *Hoeloceras*, and *Lambeoceras* are shown in text-figure 7.

Distribution: At the present time, representative of *Hoeloceras* are known only from the Oslo Region in Norway. *H. helgoeyense*, n. sp., is one of the common species in the Cephalopod shale of the Nes—Hamar district; *H. askeri*, n. sp., occurs in the Lower Chasmops limestone (4bβ) in the Oslo—Asker district.

Hoeloceras helgoeyense Sweet, n. sp.

Plate 6, figures 1—3, 5—7; text-figure 7D.

Name: The specific name, *helgoeyense*, refers to the type locality, the island of Helgøya, in Lake Mjøsa.

Type data: The holotype, P.M.O. 69266, is a incomplete internal mold of the 14 adoral camerae of the phragmocone and the adjacent part of the body chamber. It was collected by the writer from an exposure of the Cephalopod shale on the southern coast of Helgøya, in Lake Mjøsa (Nes—Hamar district).

Material: Five internal molds (in addition to the holotype), all incomplete, one partially testiferous. P.M.O. 69267, 69268 69269, 69270, 69271.

Diagnosis: A closely camerated species of *Hoeloceras* characterized by a strongly depressed (but not flattened) conch, a relatively small siphuncle, and sutures which form a slight, but distinctive mid-ventral saddle.

Description: No single one of the available representatives of this species is complete, hence the following description is based, in part, at least, on all six of the specimens at hand.

Conch orthoceraconic, expanding 1 mm in width in each 6—7 mm of length, and strongly depressed, the lateral diameter being about one and a half times the dorso-ventral diameter. Camerae short, 10 occurring in a length equal to the lateral diameter of the conch adapically, and 11 occupying this distance adorally. Septa moderately deep, with a concavity equivalent to the length of one and a half camerae. Sutures form a broad, shallow dorsal lobe, narrow lateral saddles, and a broad ventral lobe which is subdivided in the ventral mid-line by a low, sharp-crested saddle.

Surface of shell exhibits a cancellated pattern formed by the intersection of faint, closely spaced, transverse growth-lines and a series of rather prominent, but somewhat irregular longitudinal lirae. Ventral side of internal mold marked by a prominent longitudinal "furrow", which indicates the presence on that part of the shell interior of a corresponding longitudinal ridge. In addition to the prominent ventral "furrow", the internal mold also exhibits a somewhat fainter and less continuous series of longitudinal lirae. As these are similar in spacing to those developed on the shell exterior, it is possible that the shell was longitudinally "corrugated". However, these markings may represent the mural portion of cameral deposits, or they may have been formed on the interior of the shell as primary features (perhaps in association with the areas of muscle attachment) but independent of the external ornamentation.

The siphuncle is ventral and marginal in position. At the septal foramen, where the siphuncle is one-eighth the height of the conch, the septa curve gently apicad for a short distance, then are abruptly and acutely deflected away from the siphuncular axis to form short-brimmed, recumbent, angularly cyrtochoanitic necks, the length of which is equal to about one-fourth that of the camera. The connecting rings join the septal necks on the adoral side of the brim. They are broadly adnate adapically on the ventral side, but only narrowly adnate dorsally. They do not contact the septum at all adorally. Within each camera, the connecting rings expand greatly, so that, near cameral mid-length, the ectosiphuncle has a diameter equal to about one-fourth the conch height.

The ectosiphuncle is occupied by typically actinoceroid endosiphuncular deposits. These consist, in each camera, of annular rings which begin their development at the septal foramen and grow progressively orad and apicad so that, in the oldest camerae, adjacent annuli are separated only by a zone of somewhat irregular tubules or "canals" which appear to radiate outward from the vacant, subcentral portion of the siphuncle. These tubules or "radial canals" have been interpreted in other actinoceroids (*see*, for example, Teichert, 1934) to represent a siphuncular vascular system. In the specimens at hand, however, they appear to be formed by the coalescence of the irregular, tuberculated adapical and adoral surfaces of adjacent annuli, and, although these surficial irregularities may be impressions of a vascular system, they are not necessarily so. That is, they may represent only irregularities on the surface of a progressively shrinking siphuncle.

Remarks: Hoeloceras helgoeyense differs from *H. askeri*, the only other species at present referable to the genus, in that the conch is more rapidly expanding, not as strongly compressed, and the sutures do not form such deep dorsal and ventral lobes.

Distribution: This species appears to be restricted to the Cephalopod shale of the Nes—Hamar district, where it is a fairly common component of the molluscan fauna.

Hoeloceras askeri Sweet, n. sp.

Plate 2, figure 8; Plate 6, figure 4; text-figure 8 A—C.

Name: The name, *askeri*, refers to Asker Herred, southwest of the city of Oslo, within which the type locality of the species is found.

Type data: The holotype, and only known specimen, P.M.O. 69272, is an internal mold representing about 40 camerae of the phragmocone. It was collected in 1951 by Dr. Nils Spjeldnæs from the lower part of the Lower Chasmops limestone (4bβ) at Arnestadtangen, Asker (Oslo—Aker district).

Material: One incomplete internal mold, the holotype.

Diagnosis: A strongly depressed species of *Hoeloceras*, in which the conch expands rather slowly (apical angle of somewhat less than 10°) and the sutures from deep dorsal and ventral lobes.

Description: The holotype and only known representative of this new species is a distorted internal mold, 185 mm long, which is preserved in black, pyritic limestone, and consists of about 40 camerae of the phragmocone. That portion of the conch preserved expands

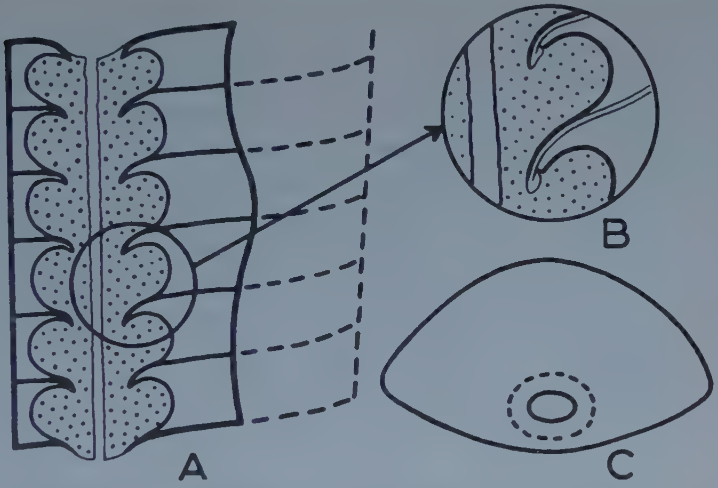

Fig. 8. *Hoeloceras askeri*, n. gen. & sp. (A) Diagrammatic dorso-ventral section through the siphuncle, x2. (B) Enlargement of that part of (A) circled, ca. x3. (C) Restored adoral conch cross-section, showing position of siphuncle, x1.

only 14 mm laterally in a length of 116 mm, which indicates an apical angle of somewhat less than 10°. As indicated by text-figure 8C, the cross-section is asymmetrically subelliptical, the venter being much more broadly rounded than the dorsum. The camerae are short and deep, but the septa are concave only laterally, being essentially flat (although ventrally inclined) in their mid-portions. Sutures form deep, broadly U-shaped ventral and dorsal lobes, and prominent, narrow lateral saddles which project adorally for a distance equivalent to the ventral length of about 4 camerae. It should be noted that, near the adoral end of the specimen, the sutures appear to form ventrolateral saddles, as in *Gonioceras*. This, however, is caused by oblique distortion of that part of the conch and no significance is attached to it.

As shown in text-figure 8A—B (and in figure 4, Plate 6), the siphuncle is large, slightly depressed, markedly nummuloidal in shape, and located close to the venter. Adjacent to the septal foramen, the septa are rather strongly curved adapically, so that the short, abruptly recurved, recumbent septal necks are directed orad in their distal portions. The connecting rings are thin, and expand widely within the camerae. They are free from the adapical surface of the adoral septum, but broadly adnate to the adoral face of the adapical septum, the width of the adnate zone corresponding to a little more than that of the recurved part of the septum itself. The cavity of the siphuncle is obviously restricted by organic deposits, but their nature can not be determined with certainty. A narrow, subcentral tubular opening, with a diameter of about 1 mm can be traced for the full length of that part of the siphuncle sectioned, but no "radial canals"or "perispatium" can be distinguished. Presumably the specimen represents the adapical part of a much larger phragmocone, hence it is probable that the siphonal cord had been reduced, in this portion of the conch, to a thin, subcentral strand.

The surface of the internal mold bears a faint series of longitudinal lirae, spaced about 2 mm apart, which may represent the mural portion of weakly developed cameral deposits. Aside from these, however, no other indication of cameral deposits is discernible.

Remarks: This species is distinguished from its somewhat older congener, *H. helgoeyense,* by its more depressed conch, deeper sutural lobes, and its relatively slight rate of adoral expansion. It might also be noted that the area of dorso-adapical adnation of the connecting rings is wider in *H. askeri* than in *H. helgoeyense,* but this difference might as easily be attributable to slight variations in the plane of the two sections or to post-mortem distortion.

Distribution: Hoeloceras askeri is known, at present, only from the Lower Chasmops limestone (4bβ) in the Oslo—Asker district.

Suborder **Michelinoceratina** Flower, 1950

[*nom. transl.* herein (*ex* Michelinoceratida Flower, 1950)].

This suborder includes the majority of orthoceraconic nautiloids of the Paleozoic, and it is well represented in the Middle Ordovician rocks of the Oslo Region. Identification of genera and proper delimitation of species within this suborder, however, requires exceptionally well preserved material, and, in addition, it is desirable to have the juvenile as well as the adult parts of the conch. That is, the siphuncle and the camerae, together with the deposits in them, may show definite ontogenetic changes which are important in recognizing and understanding relationships. Unfortunately, most of the material at hand is neither well preserved internally nor particularly complete; there are only a few long segments of the same conch available. For these reasons, it is suspected that the following diagnoses and descriptions, many based on reconstructions, include only a few of the actual number of genera and species present.

The identifiable michelinoceratinids of the Oslo Region Middle Ordovician can be separated, on the basis of their internal and external features, into four rather well defined groups:

1) Smooth-surfaced, rather closely camerated forms with a central or slightly eccentric, orthochoanitic siphuncle and no discernible cameral or endosiphuncular deposits. These forms are referred to *Sactorthoceras* Kobayashi.

2) Smooth-surfaced forms with a central or eccentric, suborthochoanitic to cyrtochoanitic siphuncle and well developed cameral, but no endosiphuncular deposits. Representatives of this group are referred to two species of *Stereoplasmoceras* Grabau.

3) Smooth-surfaced conchs like those of group 2 except that the siphuncle is constricted by a more or less continuous, non-segmental endosiphuncular "lining". Such forms are placed in *Stereoplasmocerina* Kobayashi and *Ephippiorthoceras* Foerste.

4) Variously annulated, striated, and ribbed conchs in which the internal structure appears to be like that of group 3 are referred, on the basis of external features, to *Ctenoceras* Noetling, *?Stereospyroceras* Flower, and *?Gorbyoceras* Shimizu & Obata.

In addition to forms belonging in one of the four groups just outlined, there are several specimens for which no internal information is available. Two of these were referred by Troedsson (1932, p. 14, pl. 7, fig. 7, text-fig. 3; p. 21) to *Polygrammoceras* Foerste and *Protokionoceras* Grabau, and an additional specimen is here placed in "*Kionoceras* Hyatt" with question. Descriptions of these specimens are included, largely for the sake of completeness; it has not been possible to verify their generic references.

FAMILY Michelinoceratidae Flower, 1945.

GENUS *Sactorthoceras* Kobayashi, 1934 (emend. Flower, 1946).

Sactorthoceras sp.

Plate 3, figure 12; Plate 4, figures 1, 7.

Material: Four fragmentary internal molds (P.M.O. 62973, 62974, I 1471, I 1478), only one of which (P.M.O. I 1478) retains any trace of internal structures. All, however, are from the Cephalopod shale at Hovindsholm, Helgøya, and their dimensions indicate that they probably belong in the same species.

Description: Conch a longiconic orthoceracone which is circular in cross-section and attained an over-all length of at least 70 cm, the adapical five-sixths of which represented the phragmocone. The phragmocone expands uniformly by 1 mm in each 12 mm of its length, which indicates an apical angle of about 5°. The body chamber is slightly inflated near mid-length, and an annular constriction immediately apicad of the peristome indicates that the late mature shell margin was considerably thickened. On one side of the conch, presumably the venter, the peristome is produced into a broad emargination which probably represents the hyponomic sinus.

In the adapical two-thirds of the phragmocone, the camerae are rather closely spaced, about 6 occurring in a length equal to the conch diameter. In the adoral one-third, however, only 3 camerae occupy a similar length. As shown in figure 1 on Plate 4, this change in cameral proportions occurs quite abruptly, the zone in which cameral length increases gradually being very short. The septa are shallow, saucer-shaped structures, with an adapical concavity equal to less than half the length of a camera; the sutures are simple, straight, and directly transverse to the long axis of the conch. The siphuncle is circular in cross-section, central in position, and its diameter is equivalent to one-ninth of the conch. It is composed of short, straight septal necks and thin, perfectly straight and cylindrical connecting rings. No organic deposits occur within either the siphuncle or the camerae.

Remarks: The species represented by the four specimens upon which the above description is based may well be distinct from the few others which have been referred to *Sactorthoceras*. No name is being proposed for this species, however, because my knowledge of it is based upon fragments of several different individuals which can not be conclusively associated with each other. Externally, fragments of this species may be confused with *Stereoplasmocerina approximata*, n. sp., in which the camerae are also rather closely spaced. However, the slightly depressed conch and eccentric siphuncle of the latter, together with its considerably different interior, serve to distinguish the two.

Distribution: At present, *Sactorthoceras* sp. is known only from the Cephalopod shale at Hovindsholm, Helgøya, in the Nes—Hamar district. The genus to which it belongs, however, has a wide geographic distribution, having been reported from early Middle Ordovician rocks in Korea and northeastern United States.

GENUS *Polygrammoceras* Foerste, 1927.

Polygrammoceras sp.

Plate 2, figures 7, 10.

1932. *Polygrammoceras* sp. TROEDSSON, Lunds Universitets Årsskr., N.F., Avd. 2, bd. 28, no. 6, p. 21.

Material: One partially testiferous, but almost completely recrystallized phragmocone, P.M.O. I 1714—15.

Description: Troedsson's description of this specimen reads as follows: " The specimen consists of a phragmocone, about 75 mm in length, broken at both ends, and somewhat crushed. Diameter at anterior end 18 mm. Angle of aperture about 4°. Interior structure apparently not preserved. Surface marked with longitudinal ribs which differ as much in size as in *Polygrammoceras ölandicum* but are flat on top as in *P. lineatum*. This is certainly a new species. It is derived from layers which probably belong to the basal part of stage 4b, a higher level than the Orthoceras limestone of Sweden."

Remarks: As Troedsson states, this is probably the specimen referred to *Orthoceras lineatum* His. by Kjerulf (1857, p. 285; 1865). Its reference to *Polygrammoceras* may be correct, but it should be pointed out that longitudinal striation of the shell is probably a form of ornamentation developed independently in several only distantly related groups of orthoceraconic nautiloids. The use of this external ornament taxonomically is, for that reason, open to question. For example, a specimen from Falköping, Sweden, referred by Troedsson (1932, pl. 1, fig. 6) to *Polygrammoceras lineatum* (Hisinger) has small, but well developed annulosiphonate deposits, and should probably be placed in the Ormoceratidae. *Polygrammoceras endoceroides* Troedsson, although longitudinally striated externally , has endocones and orthochoanitic septal necks, and was made the type of *Troedssonella* by Kobayashi in 1934. There is, furthermore, considerable variation in the external ornamentation, as well as in the internal structure of species referred to *Polygrammoceras* by Foerste. It appears, then, that the genus has been utilized in the past as a "catch-all" for superficially similar orthoceracones, and it is probable that the several species still retained in it do not form a natural unit. The type of *Polygrammoceras*, *P. twenhofeli* Foerste, is cyrtochoanitic, and has connecting rings which are considerably expanded within the camerae. Apparently, however, these segments do not contain secondary organic deposits. The Norwegian specimen, as Troedsson points out, does not preserve the conch interior, hence it is not known whether it agrees with the type species in siphuncular structure.

Distribution: The label which accompanies this specimen indicates only that it was collected from Stage 4b, at Løken, Bygdøy, in the Oslo—Asker district.

GENUS *Protokionoceras* Grabau & Shimer, 1910.

Protokionoceras strandi Troedsson.

1932. *Protokionoceras strandi* TROEDSSON, Lunds Univ. Årsskr., N.F., Avd. 2, bd. 28, no. 6, p. 14, pl. 7, fig. 7; text-fig. 3.

Type data: Holotype, and only known representative (P.M.O. I 0323) of this species is a body chamber from some part of the Chasmops Series in the city of Oslo.

Description: Troedsson's description of this species is as follows: "Conch slightly flattened dorso-ventrally, diameters of apertural end being 10 and 9 mm. Length of specimen about 25 mm. Apertural angle 8°. Siphuncle centren, about one-twelfth as wide as the conch. Depth of air chambers and structure of siphuncle cannot be made out. Surface marked with 37 primary longitudinal ribs: the intervals are fluted and covered with 4 or 5 secondary fine striae. The shell is also provided with transverse annulations or annuli. These are rather strong on one side — whether this is the venter or dorsum cannot be decided — and give an impression of *Spyroceras*, but on the opposite side they are almost missing, though the vertical striation is well-marked.''

Remarks: Troedsson's reference of this species to *Protokionoceras* is the best that can be made in the absence of internal structures, but it is unfortunately the case that ornamentation of the type described is probably not an infallible key to generic affinities. That is, annulation, vertical striation, cancellation, and fluting of the test occur on such a variety of conchs, not all similar internally, that it seems unwise at present to consider these features of primary importance in generic determinations.

Distribution: The only known representative of this species was collected from some part of the Chasmops Series in Waldemar Thranesgate (between Bergstien and Kingosgate), Oslo.

GENUS *Kionoceras* Hyatt, 1884.

"*Kionoceras*" sp.

Plate 15, figure 2

Material: One incomplete, recrystallized body chamber, from the Lower Chasmops shale of the Ringerike district. P.M.O. I 1859.

Description: An internal mold, 29 mm long, which is circular in cross-section and expands from a diameter of 8 mm adapically to 10 mm adorally. No trace of septa or sutures is discernible on this specimen, hence it is assumed to represent a body chamber. The surface is marked by a series of longitudinal ribs, the angular crests of which, near mid-length of the specimen, are separated by about 1 mm. The troughs of the shallow interspaces which separate adjacent ribs are less than 0.5 mm below the rib crests.

Remarks: Similarly ribbed or fluted orthoceracones have long been referred to *Kionoceras* Hyatt, regardless of their age or internal dissimilarities. Flower (1952, p. 33—38) has restudied a number of these forms and his conclusions with respect to them indicate that external ornament of the type generally thought to characterize *Kionoceras* developed several times in the past, and in several different nautiloid stocks. Consequently, in the absence of information concerning its internal structures, the specimen at hand is referred, for descriptive purposes, to "*Kionoceras*" sp. Little significance is attached to this specimen, and a description of it has been included only for the sake of completeness.

Distribution: Lower Chasmops shale, Bratterud, Ringerike.

Family Stereoplasmoceratidae Kobayashi, 1934.

Genus *Stereoplasmoceras* Grabau, 1922.

Stereoplasmoceras longicameratum Sweet, n. sp.

Plate 3, figure 5; text-figure 9A.

Name: The specific name, *longicameratum,* refers to the relatively long camerae of this new species.

Type data: Holotype (P.M.O. I 1470) is a partially testiferous internal mold of part of a phragmocone. It was collected from the Cephalopod shale at Hovindsholm, Helgøya (Nes—Hamar district).

Material: The holotype and a poorly preserved but essentially similar conch fragment (P.M.O. 1661—62) from the Ogygiocaris shale of the Hadeland district are the only two specimens which can be referred to this species with certainty at the present time.

Diagnosis: A long-chambered representative of *Stereoplasmoceras* characterized by hyposeptal and episeptal cameral deposits which have a distinctively botryoidal or algal-like structure.

Description: The holotype of this new species is a partially testiferous, fragmentary internal mold some 58 mm long, which represents 6 camerae of the phragmocone. This conch fragment is circular in cross-section and expands 1 mm in each 18 mm of its length, suggesting an apical angle of about 3°. The camerae are relatively long, only two occupying a length equivalent to the conch diameter. The septa are regularly subhemispherical in shape; the sutures are simple, straight, and directly transverse to the axis of the conch. The surface of the small areas of recrystallized test is smooth, but bears very faint, closely spaced growth-lines which are apparently parallel to the sutures.

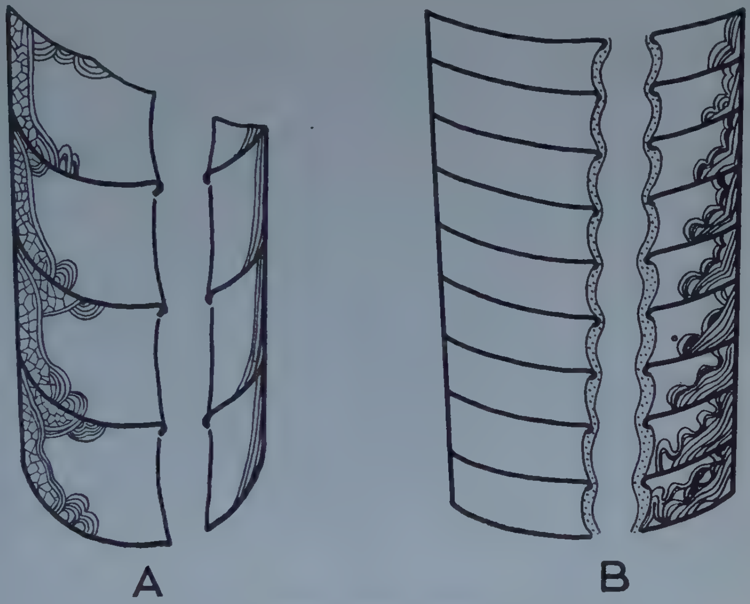

Fig. 9. (A) Diagrammatic median dorso-ventral section, ca. x2, through the holotype of *Stereoplasmoceras longicameratum*, n. sp., showing siphuncular structure and structure and disposition of cameral deposits. (B) Diagrammatic longitudinal section, x2, through the siphuncle of *Stereoplasmocerina approximata*, n. sp., based on the holotype.

The siphuncle is circular in cross-section, has a diameter at the septal foramen of about one-sixth the conch diameter, and is located between the center and the ventral margin of the conch. At a place where the conch diameter is 17 mm, the center of the siphuncle is 5 mm from the venter. It is composed of cyrtochoanitic to suborthochoanitic septal necks and thin, structureless connecting rings which expand only slightly within the camerae. In the six siphuncular segments preserved, there are no discernible organic deposits.

The camerae are occupied by both hyposeptal and episeptal deposits, the detailed structure of which is shown in text-figure 9A. These deposits consist, within each camera, of an adorally tapering, longitudinally laminated mass of calcite, laid down principally against the walls of the camera, but encroaching in the later stages of development onto the adoral surface of the septum. Insofar as I can determine, this layer is continuous around the entire circumference of the conch; however, it is considerably thinner ventrally than dorsally. On the dorsal side of the conch, the adapical portion of the peripheral deposit extends much farther toward the center of the conch than on the ventral side, and, in its inner portion, is botryoidal in structure, resembling a mass of encrusting algae.

Hyposeptal deposits are represented on the dorsal side of all 6 septa by botryoidal masses of laminated calcite which began their growth in the dorso-adoral portion of the conch, apparently after the major portion of the episeptal deposits were formed. In both the epi-, and hyposeptal deposits, there are a few laminae of much darker color. These color differences disappear in thin-section, hence it is probable that they are caused by the inclusion in some layers of disseminated organic material which is insufficient in quantity to be observable in thin-section, but sufficient to cause a marked color difference in an opaque section.

Remarks: The combination of an apparently empty, slightly cyrtochoanitic siphuncle with well developed cameral deposits indicates that the species just described belongs in *Stereoplasmoceras*. This new species differs, however, from previously described representatives of *Stereoplasmoceras*, and particularly from *S. pseudoseptum* Grabau, the type species, in that its camerae are longer, its siphuncular segments only slightly expanded, and the inner adapical edges of the dorsal cameral deposits form peculiar botryoidal structures. It should be noted that a similar structure is present in the cameral deposits on the ventral side of *Stereoplasmocerina approximata*, n. sp., which, however, has a more or less continuous endosiphuncular "lining", cyrtochoanitic septal necks, and rather broadly expanded connecting rings. It is possible that the apparently peculiar structure of the cameral deposits in these two species, and the lack of comparable structures in other representatives of the genera to which they belong are reflections only of differences in preservation.

Distribution: Stereoplasmoceras longicameratum is known at present from the Cephalopod shale at Hovindsholm, Helgøya (Nes—Hamar district) and at Hovstangen, Gran, in the Hadeland district.

GENUS *Stereoplasmocerina* Kobayashi, 1936.

Stereoplasmocerina lineata Sweet, n. sp.

Plate 5, figures 2, 5; text-figure 10C—D.

Name: The specific name, *lineata*, refers to the transversely lineated test of this species.

Type data: My knowledge of this species is based on four incomplete specimens (R.M., MO 150012, 150013, 150014, 150016) one of which is partially testiferous. All of these specimens were collected by Gerhard Holm from the Cephalopod shale at Hovindsholm, Helgøya (Nes—Hamar district). They are all considered to be of equal rank as types, hence are designated syntypes.

Material: In addition to the four syntypes, there is a body chamber (P.M.O. I 0250) from the Ogygiocaris beds at Håkavik, Asker, which resembles the syntypes, hence is referred to this species with question.

Diagnosis: A small, narrowly expanding species of *Stereoplasmocerina* with a central suborthochoanitic siphuncle, transversely banded or lineated test, thick episeptal cameral deposits and a continuous, non-segmental, endosiphuncular "lining".

Description. Conch orthoceraconic, circular in cross-section, and enlarging laterally by 1 mm in every 12 mm of length, indicating an apical angle of about 6°. Mature conch apparently 175—200 mm long, of which three-fourths is phragmocone and one-fourth body chamber. Camerae moderate in length, $2^1/_2$—3 occurring in a length equivalent to the diameter of the conch. Septa regularly subhemispherical, with a concavity slightly less than the length of a camera. Sutures straight and directly transverse to the axis of the conch. Test ornamented by a series of fine, transverse adapically imbricate growth-bands, about 10 of which occur in a length of 1 mm. Test noticeably thickened immediately apicad of the mature peristome, causing a prominent constriction in the internal mold at the adoral end of the body chamber.

Siphuncle central in position, about one-twelfth the width of the conch, and composed of suborthochoanitic (or slightly cyrtochoanitic) necks and thin, structureless connecting rings which expand slightly within the camerae. The cavity of the siphuncle is reduced by an apparently continuous, non-segmental "lining" which is of such a thickness that its inner surface is everywhere parallel to the ectosiphuncle. Camerae occupied by thick episeptal deposits which are of considerably finer grain-size than the coarsely crystalline, secondary calcite filling the balance of the conch.

Remarks: Insofar as I have been able to ascertain, *Stereoplasmocerina* is a monotypic genus, recognized heretofore only from its type species, *S. tofangoense* (Kobayashi), which occurs in the Toufangian of southern Manchuria. The genus is closely related to, and perhaps not really distinct from *Stereoplasmoceras* Grabau. That is, *Stereoplasmocerina* differs from *Stereoplasmoceras* primarily in that the siphuncle is lined with "stereoplasmic" deposits, rather than empty. The nonsegmental nature of this endosiphuncular "stereoplasm" suggests that, unlike other endosiphuncular deposits, it may have begun to accumulate in all camerae at essentially the same time, that is, after the animal had reached full maturity. Hence, it is possible that *Stereoplasmoceras* (without endosiphuncular "stereoplasm") represents only the immature stages of conchs which, at full maturity, would be referred to *Stereoplasmocerina*. It is doubtful if this problem can be solved except through a careful statistical study of a large number of specimens from the same horizon and locality, a procedure which is not possible with the Norwegian material at hand.

Stereoplasmocerina lineata differs from *S. tofangoense* (Kobayashi) in that its shell is transversely banded and its siphuncular segments are not widely expanded. It may be distinguished from its provincial contemporary, *S. approximata*, n. sp., by its smaller mature size, its relatively longer camerae, and its central, suborthochoanitic siphuncle. It is closely related to, and occurs in association with annulated nautiloids of similar size here referred to *Ctenoceras* Noetling, but differs from these in having a smooth, rather than annulated surface.

It should perhaps be pointed out that *S. lineata* is closely comparable in size, and perhaps also in internal structure, to *Orthoceratites conicus* Hisinger, which Troedsson, in 1931 (p. 24) stated he was going to make the type of a new genus, *Conorthoceras*. Opinion differs, however, as to whether such a statement can be strictly interpreted to constitute a generic designation, or whether, as Jaanusson & Mutvei (1953, p. 19, footnote 1) believe, Troedsson's name is a *nomen nudum.* I am inclined to believe that *Conorthoceras* was legally established by

Troedsson, although he did not mean to do so, and has the cited species as its type. However, neither Hisinger's nor Angelin & Lindström's illustrations of the type of *Orthoceratites conicus* suggest much as to its internal structure, hence it can not be determined at present just what should be included in it. If, as one of Angelin & Lindström's figures (1880, pl. 9, fig. 2) suggests, the siphuncle does indeed contain a more or less continuous, non-segmental lining, then it is possible that Troedsson's *Conorthoceras* and Kobayashi's *Stereoplasmocerina* are synonyms, and the former name, having priority, will have to prevail. On the other hand, it is possible that, even though the siphuncular linings may be similar, *Conorthoceras* is a distinct genus. That is, the septal necks of its type species, as illustrated by Angelin & Lindström, are quite long and perfectly straight and the siphuncle is only slightly expanded within the camerae. These, however, are features which may characterize different ontogenetic stages of the same conch in some michelinoceratinids, hence their value as generic criteria is open to question.

Distribution: Stereoplasmocerina lineata is known best from the Cephalopod shale of the Nes—Hamar district, but it probably occurs as well in the Ogygiocaris beds of the Oslo—Asker district.

Stereoplasmocerina approximata Sweet, n. sp.

Plate 4, figure 8; text-figure 9B.

Name: The specific name, *approximata*, refers to the closely spaced camerae which are one of the distinctive features of this species.

Type data: Holotype (P.M.O. 69276) a weathered, incomplete internal mold of part of the phragmocone, which has been sectioned longitudinally to expose the siphuncle. The specimen was collected from the Cephalopod shale at Hovindsholm, Helgøya (Nes—Hamar district).

Material: One incomplete specimen, the holotype.

Diagnosis and description: The holotype and only known representative of this new species is an incomplete internal mold, 110 mm long, which represents 30 camerae of the phragmocone. This conch fragment is somewhat depressed in cross-section, dorso-ventral and lateral diameters at its adapical end being 18 and 20 mm, respectively, and it expands dorso-ventrally, rather uniformly by 1 mm in each 11 mm of length. The camerae are closely, but not uniformly spaced, 5—6 occurring in a length equal to the dorso-ventral diameter of the conch. The septa are shallow, with an adapical concavity equivalent to about half the length of a camera; the sutures are straight and directly transverse dorsally and laterally, but on the venter they form broad, shallow lobes.

The siphuncle is circular in section and located between the center and the ventral side of the conch. At a place where the conch diameter is 18 mm, the septal foramen is 2 mm in diameter and the siphuncular axis is 7 mm from the venter. The siphuncle is cyrtochoanitic in structure, with short, recurved septal necks and thin-walled, subglobular connecting rings. The siphuncle is lined by an apparently nonsegmental layer of organic carbonate which is somewhat thicker ventrally than dorsally, but extends the full length of the specimen.

The ventral and lateral parts of the adapical 9 camerae are partially filled by deposits of laminated organic carbonate. These deposits are entirely episeptal and the adapical sequence in successive camerae indicates that they began as simple mural and episeptal laminae in the angle between the septum and the conch wall. From this beginning, successive crinkled laminae were added, with progressive irregularity, until, in the oldest camera retained, the space between the ventral wall and the siphuncle is almost completely occupied by an irregularly laminated mass of calcite. During the grinding of the longitudinal section (figure 8, Plate 4) from which text-figure 9B was prepared, cameral deposits were first noted in the ventrolateral zone, at a position approximately opposite the siphuncle. No deposits are discernible dorsally, but that part of the conch is somewhat less well preserved and such structures, if originally formed there, may have been obliterated.

Remarks: Stereoplasmocerina approximata, n. sp., is clearly distinct from *S. lineata*, n. sp., on the basis of its more closely and more irregularly spaced camerae and its larger, slightly depressed, more rapidly expanding conch. In addition, the siphuncular segments are more inflated, the septal necks cyrtochoanitic, and the laminae of the cameral deposits are "crinkled". Morphologically, this new species is suggestive of *Ephippiorthoceras*. However, the internal features of that genus (which presumably belongs in the same family) are not well known, and previously reported representatives of it are all considerably younger than the specimen at hand.

Distribution: The holotype, and only known specimen, is from the Cephalopod shale at Hovindsholm, Helgøya, in the Nes—Hamar district.

GENUS *Ctenoceras* Noetling, 1884.

Type species: Ctenoceras schmidti Noetling, 1884.

Noetling (1884, p. 115—116) diagnosed *Ctenoceras* as follows: "Gehäuse fast cylindrisch, sehr lang und in flachem Bogen gekrümmt. Sipho klein, subcentral, der Processualseite [= convex side] näher liegend. Septa beinahe halb kugelförmig gewolbt, Kammernähte wohl einfach ringförmig, Wohnkammer wahrscheinlich kurz, stets mit drei Eindrücken, einem unpaaren, spaltförmigen auf der Antiprocessual- [= concave-], zwei paaringen, flachen auf der Processualseite [= convex side]. Zahlreiche regelmässige und kräftige Wachsthumsrunzeln in Form schräger Ringe, getrennt durch flache Furchen werden durch die beiden Schalschichten gebildet. Schale aus zwei (?) Schichten zusammengesetzt, die äussere mit feinen, scharfen Querstreifen, parallel den Wachsthumsringen bedeckt, die innere fein gestichelt."

To this diagnosis it should be added that the types of *C. schmidti* are somewhat compressed and the annulations, as well as the growth-lines, are slightly sinuous, forming broad salients on the convex (= ventral?) side of the conch. A section through the siphuncle of an apparently congeneric Norwegian specimen indicates that, at least in the mature part of the conch, this structure is orthochoanitic, composed of short, straight septal necks, and connecting rings which expand slightly at their adoral ends. In addition, the siphuncle is lined with an essentially continuous, apparently non-segmental deposit of organic carbonate. For this reason, *Ctenoceras* is here referred to the Stereoplasmoceratidae, even though more typical representatives of this family have cyrtochoanitic (or suborthochoanitic) septal necks.

Remarks: Unfortunately, only one of the several specimens of *Ctenoceras* available to me is preserved in such a way that its internal structures can be studied, and in this specimen preservation leaves much to be desired. It undoubtedly represents a new species, but comparisons between it and the types of *C. schmidti* Noetling are difficult to draw because nothing is known of the internal structure of that species. It is perhaps presumptuous, then, to refer a large number of the annulated cyrtoceracones from the Norwegian Middle Ordovician to *Ctenoceras*. However, these specimens are externally quite similar to *C. schmidti* and an association with *Ctenoceras* is strongly implied, if not definitely established.

If, as suggested by a specimen here described as *Ctenoceras* sp. B, the siphuncle of *Ctenoceras* contains a continuous, non-segmental lining of organic calcite, it would seem to have its closest relationships with annulated stereoplasmoceratids like *Tofangocerina* Kobayashi, *Gorbyoceras* Shimizu & Obata, and *Stereospyroceras* Flower. It differs from these; however, in that the siphuncle is orthochoanitic and no deposits have been observed in the camerae. Admittedly, these comparisons are based on rather tenuous evidence; a more complete diagnosis of *Ctenoceras* will have to be based on a restudy of *C. schmidti*, which is beyond the scope of the present work.

According to Noetling (1884, p. 116, 121) *Ctenoceras* was known to him only from the Lower Ordovician Vaginatenkalk in Estonia, and from glacial boulders derived from it. It is probable, however, that Scmidt's "Vaginatenkalk" included, at the top, rocks now assigned to the Middle Ordovician Aseri Limestone (CIa). The list of fossils from a boulder of "*Ctenoceras* limestone" given by Patrunkey (1925, p. 69) contains many elements which suggest an early Middle, rather than a late Lower Ordovician age for the stratum which yielded it. Even so, the type species of *Ctenoceras*, the only species heretofore reported, seems to come from rocks somewhat older than those in which probable congeners occur in Norway. That is, nearly all of the specimens here referred to *Ctenoceras* were collected from the Cephalopod shale and, with only a few exceptions, they come from the same locality. Two specimens, including the sectioned one, come from the Lower Chasmops shale (4bα). Thus it appears that *Ctenoceras*, as herein interpreted, has a stratigraphic range from near the base of the Middle Ordovician into at least the mid-portion of the upper part of that Series. Closely related stereoplasmoceratids occur within the same stratigraphic interval in both Asia and North America.

Ctenoceras sp. A.

Plate 2, figure 2; Plate 3, figures 6, 8, 9;
Plate 17, figure 3; ?Plate 2, figure 6.

Type data: No single one of the several specimens referable to this species is particularly well preserved and nothing is known concerning their internal structures. For these reasons, no specific name is being proposed for them.

Material: Sixteen fragmentary specimens, (P.M.O. I 1430, I 1455, I 1505, I 1507, I 1508, I 1526, I 1536—37, I 1570, I 1579, I 1659, 69277, 69278, 69279, 69280, 69281, 69282) several partially septate, most preserving recrystallized portions of the test. All similar in that internal structures have been completely obliterated during preservation.

Description: All of the specimens of this group are similar in that they represent some part of an annulated, slightly cyrtoceraconic conch which expanded very slowly (about 1 mm laterally in 12 to 13 mm axially) and was somewhat compressed. Both the annulations and the growth-lines which mark the surfaces of these specimens are sinuous and form broad salients on the convex side of the conch. The siphuncle is small (about one-tenth the conch diameter) and subcentral in position. Its structure can not be determined.

Remarks: This group of specimens, which undoubtedly represents an undescribed species, is very closely related externally to *C. schmidti* Noetling. The species differs from *C. schmidti*, however, in being only slightly curved and in having a small, central siphuncle. In addition, the longitudinal impressions which mark the adoral part of the body chamber in Noetling's species have not been recognized in any of the several specimens I am studying.

Distribution: All but two of the specimens at hand come from the Cephalopod shale at Hovindsholm, Helgøya, where the species they represent appears to be rather abundantly represented. A specimen from a drift boulder in the Toten district and a similar form from Lunder farm, Hadeland belong in the same species, and probably come from the same (or essentially the same) stratigraphic horizon.

Ctenoceras sp. B.

Plate 3, figure 1; Plate 21, figure 8; text-figure 10A—B.

Type data: Incomplete conchs and poor internal preservation make it undesirable to select any of the specimens at hand as type for the undescribed species to which they almost certainly belong.

Material: Two partially testiferous internal molds (P.M.O. I 1348, I 1841) preserved in black limestone; one preserves the internal structures. In addition to these, two specimens (P.M.O. I 0386, I 1862), too fragmentary to be positively associated with either of the two just mentioned, occur in Prof. J. Kiær's collections from the Lower Chasmops shale at Bratterud, Ringerike.

Description: Conch straight or very slightly curved adapically, and somewhat compressed laterally. Camerae rather long, about 2.5 occurring in a distance equivalent to the lateral diameter of the conch. Septa deep, subhemispherical, and with a concavity equal in depth to the length of one camera. Surface of shell and internal mold transversely annulated, the annulations projecting somewhat farther orad on one side of the conch than on the other. Growth-lines fine, closely spaced, and somewhat irregular, although essentially straight and directly transverse to the long axis of the conch.

Siphuncle central in position, circular in section, and with a diameter about one-sixth that of the conch. It is composed of short, straight septal necks and thin, asymmetrically subfusiform connecting rings which expand somewhat at their adoral ends and are invaginated into the septal foramen adapically. The interior of the ectosiphuncle is lined with an apparently continuous non-segmental layer of organic calcite, parts of which appear to have been removed by post-mortem solution.

Remarks: The two specimens to which the above description refers appear to belong in an undescribed species of *Ctenoceras*, which differs from the type species of that genus in that it is not strongly curved, the annulations are not markedly bowed on the convex side, and the siphuncle is central rather than somewhat eccentric in position. The species represented by these two specimens differs from *Ctenoceras*

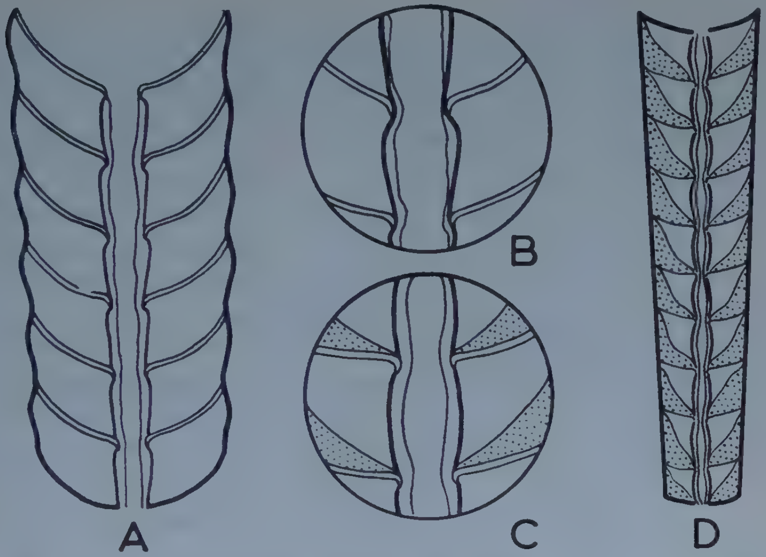

Fig. 10. (A) Schematic median dorso-ventral section, x2, through a specimen identified as *Ctenoceras* sp. B. (B) An enlargement of a part of (A), ca. x1.5, to show the ecto-, and endosiphuncular structure. (C, D) *Stereoplasmocerina lineata*, n. sp. (C) is an enlarged view of a part of (D), which is a diagrammatic view of a longitudinal section through the adapical part of one of the syntypes, x2.

sp. A, described above, in the possesion of a much larger siphuncle and in the reduced sinuosity of the growth-lines and annulations. It should perhaps be noted that the smaller of the two specimens, the one illustrated in figure 1 on Plate 3, represents the adapical portion of a conch which was broken transversely during the animal's lifetime, and later repaired. Undoubtedly, the shell was damaged at or near the aperture and later growth lines are deflected orad of this break for a distance of several millimeters.

Distribution: At present, representatives of this species are known from two localities in the Oslo—Asker district (Nakholmen Island and "Slottsveien" [= Karl Johans gate], Oslo. The Nakholmen Island specimen comes from the Lower Chasmops shale (4b*a*), and it is probable that the same horizon yielded the Oslo form.

GENUS *Ephippiorthoceras* Foerste, 1924.

Ephippiorthoceras frognoeyense Strand, 1933.

1933. *Ephippiorthoceras frognøyense* STRAND, Norsk Geol. Tidsskr., bd. 14, p. 17, pl. 3, fig. 4.

This species is fully illustrated and described in Strand's report and I can add nothing to his diagnosis of it. The form is mentioned here because the strata from which its type was collected are now regarded as uppermost Middle Ordovician (rather than lowermost Upper Ordovician) in age.

Occurence: 4bδ, Frognøya, Ringerike, 1.5 m below the black Tretaspis shale.

Repository: P.M.O. I 2109 (Holotype).

?GENUS *Stereospyroceras* Flower, 1955.

Stereospyroceras? sp.

Plate 3, figure 3.

Material: One incomplete external mold (P.M.O. I 1463—64) suggests the presence of *Stereospyroceras* in the Cephalopod shale of the Nes—Hamar district. However, I can not assign this specimen to *Stereospyroceras* with certainty for that genus can be distinguished from *Gorbyoceras* Shimizu & Obata only on the basis of structures which are not preserved in the individual at hand. The following description is based largely upon a latex cast of the external mold, and upon small fragments of the internal mold which are preserved at the adoral and adapical ends of the specimen.

Description: Conch fragment 62 mm long, slightly cyrtoceraconic, circular in cross-section, and with adapical and adoral diameters of 8.5 and 12.5 mm, respectively. The external mold is bounded by septal faces both adapically and adorally, hence the entire specimen represents part of the phragmocone. Camerae rather long, about 3 in a distance equivalent to the conch diameter; septa shallow, saucer-shaped; sutures straight and directly transverse to curving long axis of conch. Surface marked by a series of narrowly rounded transverse annulations and a prominent set of longitudinal ribs. The annulations are directly transverse to the conch axis, and alternate in position with, and are parallel to the sutures; adjacent crests rise about 1 mm above the convex interspaces which separate them. The longitudinal ribs are subangular in transverse section and continuous for the full length of the specimen. As no additional ribs appear to have been interpolated during growth, there are 32 both adorally and adapically, with the concave interspaces increasing gradually in width toward the adoral end of the specimen.

Adapically, weathering has exposed the siphuncle in one camera. At this place, it is circular in section, 1 mm in diameter, and located 2 mm from the convex (ventral?) side of the conch. It is subfusiform in shape, which suggests that the septal necks are cyrto-, or suborthochoanitic in structure, and that the connecting rings expand somewhat within the camerae. The fact that this structure now stands in relief above the septal face suggests that it was filled with organic deposits. However, if present, these deposits are not now discernible.

Remarks: The specimen at hand is reminiscent of forms from the Chazy group of New York referred to *Spyroceras clintoni* (Miller) by Ruedemann (1906, p. 445—449), later (Flower, 1946, p. 144) included in *Gorbyoceras*, and quite recently (Flower, 1955b, p. 827) placed in *Stereospyroceras*. The latter two genera are quite closely related internally, and indistinguishable externally. They differ primarily in that siphonal and cameral deposits are more advanced in *Stereospyroceras* than in *Gorbyoceras*, and known representatives of the two genera are separated by an interval which includes nearly all of the Middle Ordovician. Quite probably, as intermediate forms are described, the two genera will be found to be structural extremes in a closely related group, within which generic boundaries will be even more difficult to establish. As details of the internal structure can not be obtained from the Norwegian specimen just described, I can not refer it to either *Stereospyroceras* or *Gorbyoceras* with certainty, although it is almost certainly a member of the nautiloid group to which these two genera belong. It is here placed tentatively in *Stereospyroceras* because the rocks from which it was collected are not greatly different in age from the Chazyan of Vermont, which yielded the type species.

Distribution: Cephalopod shale, Hovindsholm, Helgøya (Nes—Hamar district).

?GENUS *Gorbyoceras* Shimizu & Obata, 1935.

Gorbyoceras? sp.

Plate 3, figure 2.

For purposes of description, a single fragmentary specimen (P.M.O. I 1846) from the Lower Chasmops shale (4b*a*) is being referred tentatively to *Gorbyoceras*, although its affinities are not at all clear.

Description: The specimen to which I refer is a partially testiferous internal mold of an annulated orthoceracone, the surface of which is further ornamented by two sets of lirae, one longitudinal, the other transverse. No trace of the internal structure is preserved and it is indeed uncertain as to whether the specimen represents phragmocone, body chamber, or parts of both. In cross-section, the conch is circular. The annuli are directly transverse to the conch axis; their crests are rather narrowly rounded, whereas the concave spaces which separate them are broad and shallow. About 5 annuli occur in a length equivalent to the maximum adoral diameter of the conch. The longitudinal lirae are of essentially equal prominence and spacing, and about 10 occur in a width of 10 mm. The transverse lirae, on the other hand, are broader, flatter, and more closely and irregularly spaced than the longitudinal ones.

Remarks: Although details of the type of surface ornamentation just described vary widely and are probably of little taxonomic significance, the specimen described differs markedly in these details from the representatives of *Ctenoceras* and *Stereospyroceras?* yielded by other strata in the Oslo Region. In the past, such specimens have been referred generally to *Spyroceras*, but that genus has a rather specialized internal structure and is probably not represented by any pre-Devonian species. The specimen at hand is similar externally to the several Upper Ordovician forms referred to *Gorbyoceras* by Flower (1946, p. 143—162) and is provisionally regarded as being congeneric. However, it should be stated unequivocally that I attach little importance to either the specimen or the identification.

Distribution: Lower Chasmops shale (4bα), Volden, Asker (Oslo—Asker district).

Suborder **Ascoceratina** Flower, 1950

[*nom. transl.* herein (*ex* Ascoceratida Flower, 1950)].

FAMILY Hebetoceratidae, Flower, 1940.

GENUS *Probillingsites* Foerste, 1928.

Probillingsites, n. sp.

Plate 5, figure 3.

Type data: The single specimen available, P.M.O. 8220, is too poorly preserved to serve as holotype for the undescribed species to which it almost certainly belongs.

Material: One incomplete specimen, an internal mold, representing two or three camerae of the phragmocone and part of the body chamber. This specimen was collected from the Lower Chasmops limestone (4bβ) at Ringsås, Ringerike, by Professor Olaf Holtedahl.

Description: The single specimen to which the following remarks pertain is an internal mold, 50 mm long, of two (or possibly three) camerae of the phragmocone and a body chamber which is incomplete adorally but retains portions of pyritized test on its left side. The conch fragment is very slightly depressed, dorso-ventral and lateral diameters at the adapical end of the body chamber being 23 and 25 mm respectively. The ventral margin of the phragmocone and the adapical two-thirds of the body chamber is convex, but on the adapertural one-third is slightly concave. The dorsal outline is concave adapically, but, near the adoral end of the specimen, it becomes slightly convex. The sides are convex, with a maximum convexity near the mid-portion of the body chamber. Only one suture, which is interpreted to represent the junction between body chamber and phragmocone, can be traced completely around the conch, but portions of at least one other (slightly apicad of the first) can be seen in the right lateral and dorsal zones. These sutures appear to be subparallel, and slope orad from venter to dorsum, forming angles of about 80° with the curved axis of the conch. The septum of truncation is not preserved ventrally, but the relatively smooth adapical continuation of the dorsal profile toward the venter suggests that this septum was essentially parallel to the sutures and not deeply (although asymmetrically) concave.

The test exhibits a series of fine growth-lines which are straight and essentially perpendicular to the curved axis of the conch ventrally, but slightly oblique laterally and dorsally. These lines are somewhat farther apart ventrally than dorsally, which suggests that the aperture sloped adapically toward the dorsum.

Remarks: In general configuration, this specimen of *Probillingsites* is not unlike others (including the type species) which have previously been described. It apparently belongs to that group of species in which the septa are subparallel (rather than dorsally divergent). However, the inclination of the septa with respect to the conch axis is considerably less in the Norwegian species just described than in congeneric, but probably somewhat younger American forms.

Distribution: Lower Chasmops limestone (4bβ), in the Ringerike district. If the correlations between the Norwegian section and that of North Amercia suggested in Table I are correct, this is the oldest recorded occurrence of *Probillingsites*.

Suborder Oncoceratina Flower, 1950

[*nom. transl.* herein (*ex* Oncoceratida Flower, 1950)].

FAMILY Oncoceratidae Hyatt, 1883.

GENUS *Oncoceras* Hall, 1847.

Oncoceras sp.

Plate 1, figure 6.

Material: One fragmentary internal mold, P.M.O. I 1531, which does not preserve any of the internal structures of the conch.

Description: The single specimen here referred to *Oncoceras* is a fragmentary internal mold, 50 mm long, which represents 4 camerae of the phragmocone and the adjacent part of the body chamber. The conch is very slightly compressed, dorso-ventral and lateral diameters at the adapical end of the body chamber being 25 and 24 mm, respectively. Only a short segment of the dorsum is preserved, but it is nearly straight. The venter, however, is markedly curved and the sides are slightly convex, converging both adapically and adorally. The camerae are longer ventrally than dorsally, apparently rather shallow, and the fact that the adoral camera is somewhat shorter than those preceding it suggests that the specimen represents a mature individual. The aperture is not preserved, nor are any of the internal structures discernible. A small subcircular structure near the venter at the adapical end may represent the siphuncle, but this can not be confirmed.

Remarks: The specimen described briefly above, although incomplete, exhibits a majority of the features which characterize *Oncoceras* Hall as that genus is presently understood (Flower, 1946, p. 240—246). That is, the maximum conch diameters are near the adapical end of the body chamber (rather than farther orad as is generally the case in the closely related *Beloitoceras* Foerste). The conch is not, however, inflated dorsally, and it is similar to the less gibbous representatives of *Beloitoceras* in this respect.

Distribution: The horizon and locality from which the described specimen was collected are not known. It is probable, however, that it, like most of the others with which it is catalogued, came from the Cephalopod shale in the area in and around Lake Mjøsa.

GENUS *Beloitoceras* Foerste, 1924.

Beloitoceras stoermeri Sweet, n. sp.

Plate 5, figure 1; Plate 17, figure 1; Plate 21, figure 7.

Name: The specific name, *stoermeri*, is proposed in honor of Professor Leif Størmer, Professor of Historical Geology and Paleontology at Oslo University, and Director of the Paleontological Institute in that institution.

Type data: The holotype, P.M.O. I 1860, is a compressed and somewhat distorted, testiferous internal mold which has been sectioned longitudinally to expose the siphuncle. This specimen was collected in 1913 by Professor J. Kiær from the Lower Chasmops shale of the Ringerike district.

Material: In addition to the holotype, Professor Kiær's collections from the same locality and horizon contain an incomplete internal mold of the adoral part of an oncoceratinid conch (P.M.O. I 0387) which appears to be conspecific with the holotype of *B. stoermeri*, n. sp., and is here associated with it without question.

Diagnosis: A species of *Beloitoceras* characterized by an only slightly gibbous conch and a dorsum which is concave throughout its length. The species belongs in the form-group typified by *B. clochense* Foerste, but is larger and somewhat less strongly compressed than previously described representatives of this form-group.

Descriptions: The holotype, which is about 57 mm long, is a distorted internal mold of 11 camerae of the phragmocone and the adjacent adapical part of the body chamber. It has been crushed adorally, but adapically it appears to be little distorted. In its undistorted adapical portion, the conch is subovate in cross-section, and higher than wide, having lateral and dorso-ventral diameters of 14 and 15 mm, respectively. The venter, which is somewhat more narrowly rounded than the dorsum, is convex and regularly curved longitudinally, and in profile it describes an essentially circular arc with a radius of about 50 mm. The dorsum is longitudinally concave adapically, but becomes nearly straight adorally. The sides appear to be very faintly convex. The camerae are short and the septa only slightly concave. The two adoral camerae are only half the length of those preceding them, which indicates that the specimen represents a mature individual. The sutures are virtually straight, but form broad lateral lobes and low ventral and dorsal saddles. The test is transversely rugose, exhibiting a series of low "wrinkles" and growth-bands which are, in general, parallel to the sutures.

The siphuncle is rather small and located near the ventral margin of the conch. At the adapical end of the specimen, it is 1 mm in diameter and situated 1 mm from the venter; at the adoral end of the phragmocone, it is about 3 mm in diameter, and some 2 mm from the conch margin. Throughout the length of the specimen, the siphuncle is composed of short, suborthochoanitic septal necks and thin connecting rings which expand only slightly within the camerae, their maximum width being attained in the adapical third of their length. Dorsally, but not ventrally, the adapical part of the connecting ring is adnate to the adoral surface of the septum for a short distance. The siphuncle contains no secondary organic deposits, nor do any occur in those parts of the camerae which are preserved.

The smaller of the two specimens here referred to *B. stoermeri*, n. sp., is 48 mm long, is coarsely recrystallized, and consists of the partially testiferous internal mold of a body chamber and probably two or three camerae of the phragmocone. It is slightly compressed in cross-section; the ventral profile is regularly and rather markedly convex, whereas the dorsal outline is concave adorally, but straight to gently convex in its adapical portion. The sides are convex and converge both adapically and adorally. The aperture is not preserved. The test is marked by a series of fine, irregular growth-rugosities which slope laterally from venter to dorsum. None of the internal structures are preserved.

Remarks: A large number of species of *Beloitoceras* have already been proposed, but, insofar as I am aware, none have heretofore been recognized in the Middle Ordovician of the Scando-Baltic province. A majority of the known Middle Ordovician species come from North America, and representatives of the genus have also been reported from Greenland. Many of these species are based on incomplete or poorly preserved material, and they are said to differ from one another chiefly in amount of curvature, size, position, and extent of adoral gibbosity, length of camerae, and form of the sutures. By and large, little information is available concerning the structure of the siphuncle or the range of variation within the several described specific groups. There can be no doubt that there is considerable morphological difference exhibited by the described species of *Beloitoceras*, but the taxonomic significance of these is, of course, a matter of opinion. The specimens at hand fall well within the morphological limits of *Beloitoceras*, as that genus is generally interpreted. However, they differ in a number of respects from all the types recorded in the literature as much, at least, as those specimens differ from one another.

Beloitoceras stoermeri, n. sp., probably belongs in and seems to be characteristic of a group of species typified by *B. clochense* Foerste (*see* Flower, 1946, p. 268—9). In this group, the conch is only slightly gibbous and the dorsum is concave throughout its length. Although the Norwegian species is somewhat larger than the majority of forms referable to this group, it is not unlike slightly curved members of it such as *B. carveri* (Clarke), *B. huronense* Foerste, and *B. bucheri* Flower. However, in addition to being larger (and probably somewhat older) then the types of any of these species, *B. stoermeri* is also less strongly compressed. No specific information concerning the siphuncular structure of any of the 3 North American species just mentioned is available, but they appear to have siphuncles similar at least in size and position to that of *B. stoermeri*.

Distribution: At present, *Beloitoceras stoermeri* is known only from two specimens, both of which came from the Lower Chasmops shale (4bα) at Bratterud, on the west side of Røysetangen in the Ringerike district of the Oslo Region.

FAMILY Allumettoceratidae Flower, 1946.
GENUS *Allumettoceras* Foerste, 1926.
Allumettoceras mjoesense Sweet, n. sp.

Plate 3, figure 7; Plate 4, figure 5; Plate 21, figure 9.

Name: The specific designation, *mjoesense*, refers to Lake Mjøsa (Nes—Hamar district) in which Helgøya, the type locality, is situated.

Type data: As holotype, I am designating the specimen illustrated in figure 5 on Plate 4 (P.M.O. 69283). The remaining four specimens P.M.O. 69284, 69285, 69286; R.M. MO 150038) are regarded as paratypes, and information concerning the internal structures of the conch has been derived from them.

Material: Five incomplete internal molds, four of which are preserved in dark gray limestone, the fifth in pyrite. All but the holotype have been sectioned longitudinally. All are from the same horizon and locality, the Cephalopod shale on Helgøya (Nes—Hamar district).

Diagnosis: A relatively large, rapidly expanding species of *Allumettoceras* which differs from previously described species of the genus in that the venter is broadly rounded (rather than flattened) and the siphuncle is somewhat more removed from the ventral margin of the conch than appears to be "typical".

Descriptions: The holotype is an incomplete internal mold, 57 mm long, which represents 10 complete camerae of the phragmocone and parts of two more. It is subelliptical in cross-section, having dorsoventral and lateral diameters at the adapical end of 17 and 24 mm, respectively. The conch expands laterally by 8 mm in 30 mm of length, which indicates an apical angle of about 15°. The camerae are short, 8 occurring in a length equivalent to the lateral diameter of the conch.

The septa are shallow and the sutures sinuous, forming prominent ventral and very slight dorsal lobes separated by broadly rounded lateral saddles. The siphuncle is circular in section and, at the adapical end of the specimen, has a diameter of 2 mm. At this place, it is located 3 mm from the ventral margin of the conch.

The mid-ventral surface of the internal mold is marked by a rather prominent set of longitudinal ribs or ridges which appear to be separated into two series, one on either side of the mid-ventral line. Similar, but less prominent markings occur around the remainder of the conch circumference. These may represent the molds of vestigial organic deposits in the camerae or may, in some way, be associated with the muscle attachment areas.

The structure of the siphuncle is well illustrated by a specimen similar to the holotype externally, but somewhat larger in over-all dimensions. As shown in figure 9 on Plate 21, the siphuncle of this specimen is cyrtochoanitic, composed of septal necks which are more strongly recurved dorsally than ventrally, and thin, apparently structureless connecting rings which expand only slightly within the camerae. There are no organic deposits within the siphuncle.

The specimen illustrated as figure 7 on Plate 3, is 52 mm long, and represents 6 camerae of the phragmocone. The conch is depressed; near the adapical end of the specimen, dorso-ventral and lateral diameters are 30 mm and 23 mm, and 14 mm orad of this these dimensions are 32 and 24 mm, respectively, suggesting and apical angle of only 8°. Both the dorsum and venter are broadly arched, whereas the sides are much more narrowly rounded. The venter has been etched by weathering, but it does not appear to have been flattened nor to have had a convexity significantly less than that of the dorsum. The camerae are short; the septa are shallow, with an adapical convexity equivalent to about the length of half a camera. The sutures are sinuous, and directly transverse to the long axis of the conch. Dorsally and laterally they are essentially straight, but ventrally they form a broad shallow lobe, the depth of which has been greatly accentuated by weathering.

The siphuncle is preserved in the adapical 2 camerae. It is cyrtochoanitic in structure, composed of rather long, gently recurved septal necks, and thin connecting rings which expand only slightly within the camerae. At the adapical end of the specimen, the siphuncle is circular in section, 4 mm in diameter, and located 4 mm from the ventral margin of the conch (or about half-way between the venter and the center). Apparently there are no secondary deposits either in the siphuncle or in the camerae. However, it should be pointed out that, as in the holotype, the surface of the internal mold is marked by a series of fine longitudinal ribs or ridges, several of which extend the full length of the specimen and are broken only where they cross the sutures.

Remarks: As the above descriptions indicate, there is some slight variation between the available representatives of *Allumettoceras mjoesense*, n. sp., in rate of conch expansion and disposition of the surficial markings on the internal mold. They are, nevertheless, all of the same age and all so similar internally that there seems to be no good reason for assigning specific significance to these morphological variations. The new species described falls well within the limits of *Allumettoceras* as that genus is presently understood, and differs from congeneric forms only in that the venter is not noticeably flattened and the siphuncle is somewhat more removed from the margin than appears to be typical.

Distribution: All of the available representatives of *Allumettoceras mjoesense* come from the Cephalopod shale at Hovindsholm, Helgøya, in the Nes—Hamar district of the Oslo Region, Norway. The genus *Allumettoceras* has a rather extended range within the Ordovician, having been reported from rocks which range in age from early Middle Ordovician (Marmorian) through the Upper Ordovician (Richmond) of the western United States.

?GENUS *Tripteroceras* Hyatt, 1884.

Tripteroceras? problematicum Sweet, n. sp.

Plate 2, figure 4; Plate 21, figure 5.

Name: The specific name refers to the doubtful taxonomic position of this new species.

Type data: The holotype and only known representative of this new species (P.M.O. I 1340) is a fragmentary internal mold which has been sectioned longitudinally to expose the siphuncle. It was collected from the Lower Chasmops shale (4bα) in the Ringerike district by Professor J. Kiær, in 1913.

Diagnosis: A species of nautiloid cephalopods, probably referable to *Tripteroceras* Hyatt, characterized by a conch that is subtriangular in cross-section and by sutures which form a low, but prominent mid-ventral saddle.

Description: The holotype is 29 mm long, and represents about 11 camerae of the phragmocone. It has adapical dorso-ventral and lateral diameters of 8 and 9 mm, respectively, and expands rather slowly so that comparable measurements 12 mm orad of the adapical end are only 9 and 10 mm. The cross-section of the conch is subtriangular; the ventral side is broadly arched and nearly flat, the lateral zones are also broadly convex and converge toward the dorsum, which is acutely rounded and almost angular. The septa are deep, subhemispherical, and project adapically in their free portions for a distance equivalent to the length of a camera. Sutures are prominently sinuous, forming low, pointed saddles flanked by shallow lobes on the venter, broad saddles in the ventrolateral zones, deep lateral lobes, and, presumably, rather sharp saddles on the dorsum. The siphuncle is small, empty, and submarginal in position. The septal necks are strongly and abruptly recurved; the thin, apparently structureless connecting rings expand rather widely in the adapical part of each camera, but are essentially straight, or even slightly incurved, adapically. No endosiphuncular or cameral deposits are discernible.

Remarks: Superficially, the specimen just described bears a considerable resemblance to the three known species of *Clinoceras* Mascke (Mascke 1876; Dewitz, 1880, p. 173, pl. 4, fig. 1; Patrunkey, 1926, p. 114). That is, the configuration of the sutures, particularly on the venter, is strikingly like that of *Clinoceras dens* Mascke, which, however, has an asymmetrically ovate conch cross-section. The siphuncle of *Clinoceras*, however, appears to be considerably different from that of the specimen at hand in that the septal necks are not strongly recurved and the connecting rings are faintly plano-convex, the side nearest the wall of the conch being somewhat flattened. In that the conch of the Norwegian specimen is subtriangular in cross-section, it is similar to the several known species of *Tripteroceras*. It differs from all of them, however, in that the sutures form prominent midventral crests. Internal comparisons are not possible, for the siphuncular structure is not known in detail for any previously described representative of *Tripteroceras*. Presumably, however, the siphuncle in this genus is cyrtochoanitic and unoccupied by any later endosiphuncular deposits. For these reasons, then, the fragmentary form at hand (which clearly represents an undescribed species) can not be associated with *Tripteroceras* or any other genus with certainty.

Distribution: Lower Chasmops shale (4bα) at the west side of Røysetangen, Ringerike.

FAMILY Valcouroceratidae Flower, 1946.

?GENUS *Valcouroceras* Flower, 1943.

Valcouroceras? holtedahli Sweet, n. sp.

Plate 5, figure 6; Plate 21, figure 6; text-figure 11A—B.

Name: This new species is named in honor of Professor Olaf Holtedahl, of Oslo University, who collected its holotype.

Type data: The holotype (P.M.O. I 1669—70) and only known representative of this species is a weathered fragment of part of a small phragmocone which has been sectioned longitudinally to expose the siphuncle. It was collected from the upper part of the Ogygiocaris Series (probably from the Cephalopod shale) in the Hadeland district.

Diagnosis: A valcouroceratid species, perhaps referable to *Valcouroceras* Flower, characterized by a compressed, exogastric conch, short camerae, and a subventral, suborthochoanitic to slightly cyrtochoanitic siphuncle occupied even in early stages by prominent actinosiphonate deposits.

Description: The holotype and only known representative of this new species is an internal mold, 26.5 mm long, which represents 11 camerae of a small, slightly cyrtoceraconic, exogastric conch of lachrymiform cross-section, the dorsum being broadly rounded and the venter subangular. The camerae are short, the septal concavity equivalent to about the length of one camera, and the sutures sinuous, forming sharp-crested ventral and low, broad dorsal saddles with intervening shallow lateral lobes. None of the original test is preserved,

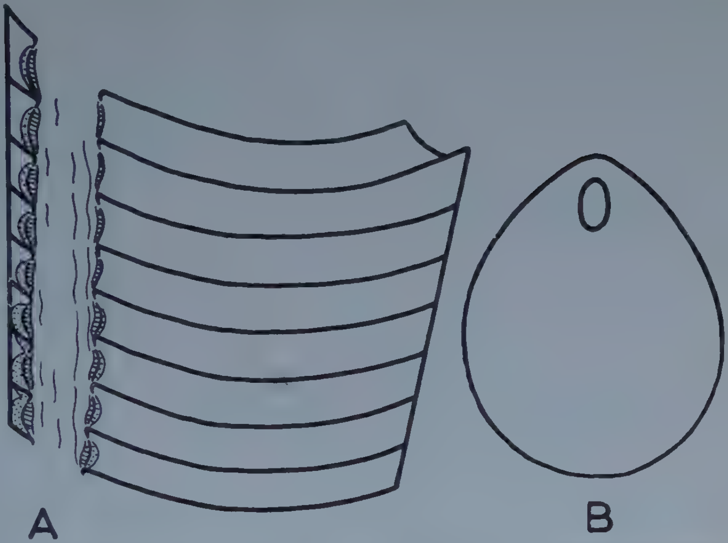

Fig. 11. *Valcouroceras? holtedahli*, n. sp. (A) Diagrammatic median dorso-ventral section, x3, through the holotype. (B) Outline view, x2, of the adoral septum of the holotype.

but the surface of the internal mold shows a series of rather coarse, raised longitudinal lines which suggests that the inner surface of the shell was, for some reason, of irregular circumferential thickness.

Figure 6 on Plate 21, and text-figure 11A, which is an enlarged, diagrammatic view of the same dorso-ventral section through the holotype, show that the siphuncle is subventral in position, has a diameter equivalent to about one-sixth that of the conch, and is composed of suborthochoanitic or only faintly cyrtochoanitic septal necks, and connecting rings which expand slightly within the camerae. Within the connecting rings there are secondary organic deposits consisting of cresent-shaped annuli, the adapical ends of which are produced into the siphuncular cavity as a series of longitudinal, radial blades or rays. These deposits are undoubtedly actinosiphonate structures, but their detailed morphology can not be determined from the material at hand which has been somewhat recrystallized.

Extrasiphuncular deposits, almost certainly organic in nature, form annuli about the connecting rings. These deposits are most advanced adapically, where they virtually fill the camerae on the ventral side of the siphuncle; adorally, however, they are thinner, which suggests that their development within any one camera was delayed until a considerable length of conch had been formed beyond it. On the dorsal side of the conch, the camerae are filled with coarsely crystalline calcite, hence any organic deposits that may have formed there are now indistinguishable.

Remarks: Representatives of the Valcouroceratidae, which family includes only six genera at present, have been reported previously only from the North American Middle and Upper Ordovician. The family was erected by Flower (1946, p. 335) to include exogastric, cyrtochoanitic cyrtoceracones of subtriangular cross-section, which almost certainly developed from the Oncoceratidae, but differ from typical members of that family in that there are actinosiphonate deposits in the siphuncle. The holotype of *Valcouroceras? holtedahli* is similar externally to the several Chazyan (Marmorian) species of *Valcouroceras* described by Flower in 1943a and 1955b, particularly to the adapical ends of those forms. However, as Flower pointed out in 1943a, and again in more detail in 1946 (p. 339—343), actonisiphonate deposits are well developed only in the adoral end of the siphuncle in typical members of *Valcouroceras*, whereas earlier portions of the siphuncle are vacant or have only simple endosiphuncular annuli. In that annulosiphonate deposits are apparently well developed in *V.? holtedahli*, it is more like *Augustoceras* Flower (=? *Wetherbyoceras* Foerste), but typical representatives of that genus are broader in cross-section, having strongly recurved septal necks, and are, at present, known only from rocks of early Upper Ordovician age in North America.

From its stratigraphic position and a structural pattern which seems to include both primitive and advanced features, it would appear that *V.? holtedahli* is probably best regarded as a regional variant of the Valcouroceratidae, in which are combined the compressed conch and suborthochoanitic septal necks of the early part of *Valcouroceras* and the more completely elaborated endosiphuncular deposits of *Augustoceras*. Undoubtedly, when more nearly complete representatives of this species are discovered, it will be necessary to propose a new generic name for them. At the present time, however, the principal significance of *V.? holtedahli* is that it is one of the few components of the early Middle Ordovician nautiloid fanua now known from Norway which appears to be at all closely related to essentially contemporaneous North American forms.

Distribution: Valcouroceras? holtedahli, n. sp., is known at present only from the holotype, which was collected from the upper part of the Ogygiocaris Series, probably from a horizon in general equivalent to the Cephalopod shale of the Nes—Hamar district, at Hovstangen, Gran, in the Hadeland district.

FAMILY Diestoceratidae Foerste, 1926.

GENUS *Diestoceras* Foerste, 1924.

Diestoceras sp.

Plate 1, figure 3.

Material: One distorted specimen, P.M.O. I 0565, from the uppermost part of the Middle Ordovician in the Ringerike district.

Description: The single specimen here referred to *Diestoceras* Foerste is a flattened internal mold, 38 mm long, preserved in grayish-brown shale. It represents 8 camerae of the phragmocone and an essentially complete body chamber. Insofar as I can determine, the conch axis was originally perfectly straight and the sides diverged regularly on the phragmocone and contracted smoothly and evenly over the short body chamber.

The sutures are straight and directly transverse to the conch axis. The surface of the internal mold bears a series of coarse longitudinal markings similar to those found in other representatives of *Diestoceras* and an indistinct "basal zone", marked by a faint, transversely serrate line, exists at the adapical end of the body chamber. The apertural margin is not preserved and none of the internal structures are discernible.

Distribution: The specimen described briefly above was collected from the upper part of substage 4bδ, on Frognøya in the Ringerike district of the Oslo Region. The genus becomes abundant, and is known from several species in the Upper Ordovician strata of the Oslo Region (Strand, 1933, p. 85—87).

Suborder Tarphyceratina Flower, 1950

[*nom. transl.* herein (*ex* Tarphyceratida Flower, 1950)].

FAMILY Trocholitidae Chapman, 1857.

Subglobar to discoidal nautilicones with 3 to 5 or more slowly expanding, dorsally impressed whorls, and a long body chamber which, in most genera, tends to become free from the inner whorls adaperturally. Camerae short, sutures simple, or forming broad ventral, lateral, and dorsal lobes with somewhat narrower saddles on the ventrolateral and umbilical margins. Siphuncle marginal, or dorsad of center except in initial volution where it may have a central or ventral position. Septal necks short, orthochoanitic; connecting rings typically thickened, but are thin, at least adapically, in *Trocholites*. Surface sculpture variable in prominence but consistent in being composed of adapically imbricating growth-lamellae which form deep ventral sinuses. In many forms periodic constriction of the shell results in a series of sinuous transverse annulations which also form deep ventral sinuses.

As thus defined, the family includes the Ordovician genera *Trocholites*, *Discoceras* [= *Schroederoceras*], *Curtoceras*, *Arkoceras*, *Jasperoceras*, *Litoceras*, *Trocholitoceras*, *Wichitoceras*, *Hardmanoceras*, and the Silurian *Graftonoceras*. A large majority of the Ordovician forms referable to this family are known only from rocks of Upper Canadian (= Arenigian) age in North America, but several have been reported from strata of similar age in Australia. Two of the dominantly Lower Ordovician genera, *Curtoceras* and *Hardmanoceras*, are represented by species in the early Middle Ordovician, and the genera *Trocholites* and *Discoceras* appear to be restricted entirely to the Middle and Upper Ordovician.

GENUS *Trocholites* Conrad, 1838.

Type species: Trocholites ammonius Conrad, 1838.

Small, gradually expanding nautilicones, typically subdiscoidal in shape, with 5 or more volutions and a body chamber one-half to three-fourths of a volution long which does not diverge from preceding volutions. Whorl section broadly reniform; dorsal part of whorl impressed, but impressed zone rarely deep. Umbilicus wide, in most species not deep; umbilical perforation small. Siphuncle orthochoanitic in structure, and dorsal or subdorsal in position at all stages of growth. The connecting rings are thin[1]. Surface sculpture variable, but in most forms it consist of fasciculate growth-lines (or bands) and ribs which form ventral sinuses. In a few species a faint ventral keel appears on the outer whorl, and variously developed nodes or tubercles have been reported to occur in the umbilical regions.

Trocholites is known to occur in Europe, North America, and Asia, and to have a stratigraphic range from early Middle through Upper Ordovician. The genus is distinguished from other closely related forms by its generally small size and its persistently marginal dorsal siphuncle. Although here described as a species of *Trocholites*, further studies of well preserved representatives of the subglobular *T. hospes* (Remelé) may indicate that it is structurally, as well as morphologically, distinct from *Trocholites*, as Remelé, Foerste, and Strand have suggested. This species was originally referred to the genus *Palaeonautilus*, as were other similarly globular trocholitids. At the present time, however, there seems to be no logical reason to separate forms with inflated whorls from *Trocholites*.

Trocholites depressus (Eichwald).

Plate 7, figures 3—7; text-figure 12.

1840. *Nautilus depressa* Eichwald, Ueber das silurische Schichtensystem von Ehstland. St. Petersburg. p. 106.

1860. *Clymenia depressa* Eichwald, Lethaea Rossica, pt. I, v. 2, p. 1350, pl. 50, fig. 5a—b.

1880. *Palaeonautilus depressus* Remelé, Festschr. f. die 50 jährige Jubelfeier der Forstakad., Eberswalde, p. 246; ————, 1881, Zeitschr. d. deutsch. geol. Ges., Bd. 33, p. 13.

1882. *?T. depressus* Schröder, Physikal.-ökon. Ges. zu Königsberg, Schriften, Bd. 23, p. 98.

1882. *?T.* cf. *incongruus* Schröder, ibid., p. 97.

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[1] Dr. R. H. Flower has written me that *Trocholites* can have thickened connecting rings, but that they show best in later whorls. Some small species, such as the ones from the Norwegian Middle Ordovician, do not show this thickening well, although its apparent absence may be little more than a matter of scale.

1891. *T. depressus* Schröder, Paleont. Abh. v. Dames & Kayser, N. F., Bd. 1 (whole ser. Bd. 5) Hft. 4, p. 13, pl. 1 (24), fig. 4, 7.
1926. *T. depressus* Patrunkey, Zeitschr. f. geschiebeforsch., Bd. 2, p. 125.
1953. *T. depressus* Balaschov, Trudy V.N.E.G.R.I., n. s., no. 78, p. 242—3, pl. 7, fig. 2.

Material: In the collections I am studying, there are 7 specimens, (P.M.O. I 0491, I 1460, I 1755, I 1839, I 2407, 69287, 69288), all from some part of the Ogygiocaris Series, which compare very favorably with the type of *T. depressus* (Eichwald), and almost certainly belong in that species as it is presently understood. All are internal molds; only one preserves any trace of the surface sculpture.

Description: All of the specimens at hand are internal molds of some part of a subdiscoidal nautiliconic conch. The most nearly complete of these (figures 4 and 6 on Plate 7) have over-all diameters (measured across the umbilicus) of 30 and 34 mm, and consist of 5 rather slowly expanding volutions which are broadly reniform in cross-section. The outer half-volution represents the body chamber. The camerae are relatively long, about 3 occurring in a distance equivalent to the lateral diameter of the conch. Sutures are essentially straight, and directly transverse to the axis of the conch, but, owing to conch shape, they form slight dorsal and lateral lobes, and saddles on the venter and umbilical seams.

As is clear from text-figure 12, the siphuncle is small and marginodorsal in position as far apicad as it can be traced. Its structure can not be determined from any of the specimens at hand, but presumably, as in other trocholitids, it is orthochoanitic.

Only one specimen (figure 5 on Plate 7) is preserved in such a fashion that any of the surface sculpture can be seen. This takes the form of slightly oblique ribs which are most prominent on the innermost volutions but very faint on that part of the body chamber preserved. Small test fragments on the body chamber of the same specimen show a series of fine, sinuous growth-lines, which are fasciculate, and form deep, rounded ventral sinuses.

Remarks: Trocholites depressus is apparently quite similar to *T. incongruus* (Eichwald), with which it is associated stratigraphically, but differs from the latter primarily in being somewhat larger. The pattern of ornamentation here described seems closer to that illustrated

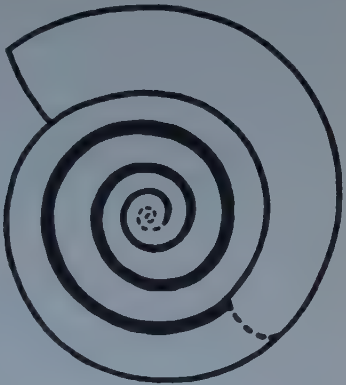


Fig. 12. *Trocholites depressus* (Eichwald). Schematic view of a median longitudinal section through the specimen shown in figure 5, Plate 7, x2. Heavy dark line on dorsal side of inner whorls represents the siphuncle.

by Schröder for *T. depressus* than to that shown by him for *T. incongruus*, but it is difficult to attach any particular significance to minor differences in ornamentation. The two species of Flower (1943b, p. 79, pl. 5, fig. 6, 7; p. 81, pl. 5, fig. 4, 5) from the Valcour limestone (Marmorian) of New York are similar in size to the forms here described, but *T. ruedemanni* expands more rapidly (and is, therefore, much like *T. hospes* (Remelé)) and *T. gracilis* has a narrowly rounded venter in the outer volution, as does *T. ammonioides* Kobayashi (1934, p. 428, pl. 26, fig. 1—3) from the Chikunsan beds of Makkol, in southern Korea.

Distribution: Representatives of *T. depressus* occur in Norway in the Upper Didymograptus shale ($4a\alpha_{1\text{-}2}$) at Huk, Bygdøy, at Bakkebukt, and at Fornebo, all in the Oslo—Asker district, and a single specimen is known from the Cephalopod shale at Hovindsholm, Helgøya, in the Nes—Hamar district. The holotype of the species was collected by Eichwald from the Lasanmäe limestone of Estonia.

Trocholites contractus Schröder.

Plate 7, figures 1, 2.

1891. *Trocholites contractus* SCHRÖDER, Paleont. Abh. v. Dames & Kayser, N.F., Bd. 1 (whole ser. Bd. 5) Hft. 4, p. 19, pl. 1 (24), fig. 2.
1926. *T. contractus* PATRUNKEY, Zeitschr. f. geschiebeforsch., Bd. 2, p. 125.

Material: A single internal mold, P.M.O. I 1461—2.

Description: The single representative of this species in the collections I am studying, is a steinkern of a small, thickly subdiscoidal nautiliconic conch, about 20 mm in diameter (measured across the umbilicus), the 4 or 5 whorls of which are reniform in cross-section and expand rather gradually orad. The body chamber occupies the outer half-volution; the aperture is not preserved. The camerae are short; the sutures form slight ventral, lateral and dorsal lobes, with low, narrow saddles on the ventrolateral and umbilical margins. As shown in figure 2 on Plate 7, the siphuncle is small, tubular, and marginodorsal in position.

Remarks: The small size of the specimen, together with the fact that the camerae do not shorten adorally, suggests that it represents an immature individual. Nevertheless, the rate of adoral expansion in the outer volution appears to be somewhat less than that of the inner ones, and there is no measurable increase in height within the length of the body chamber. Both of these features distinguish the holotype of *T. contractus* from other, similar species.

Distribution: In Norway, *T. contractus* occurs in the Cephalopod shale at Hov, in the Toten district.

Trocholites hospes (Remelé).

Plate 8, figures 3, 5.

1880. *Palaeonautilus hospes* Remelé, Festschr. f. die 50 jährige Jubelfeier der Forstakad., Eberswalde, p. 249, pl. 2, fig. 3—4; — — —, 1881, Zeitschr. d. deutsch. geol. Ges., Bd. 33, p. 13.
1882. *Trocholites hospes* Schröder, Physikal.-ökonom. Ges. zu Königsberg, Schriften, Bd. 23, p. 100.
1891. *T. hospes* Schröder, Paleont. Abh. v. Dames & Kayser, N. F., Bd. 1 (whole ser., Bd. 5), Hft. 4, p. 17—18, pl. 1 (24), fig. 8, 9.
1926. *T. hospes* Patrunkey, Zeitschr. f. geschiebeforsch., Bd. 2, p. 125.
1929. *Palaeonautilus hospes* Foerste, Denison Univ. Bull., Jour. Sci. Labs., v. 24, p. 286—288, pl. 43, figs. 2A, 2B; pl. 44, figs. 4, 5.
1953. *T. hospes* Balaschov, Trudy V.N.E.G.R.I., n.s., no. 78, p. 244—245, pl. 5, figs. 3a—c.

Material: One internal mold of an essentially complete conch, R.M. MO 150030) and one incomplete internal mold (P.M.O. 69289).

Description: The most nearly complete of the two specimens is an internal mold in black limestone which is 53 mm in maximum diameter (measured across the umbilicus) and represents about $5^1/_8$ volutions of a rapidly expanding, subglobular, deeply umbilicate conch.

The whorls are very broadly reniform in cross-section, having a width to height ratio of about 3:2 at the adoral end. The outer half-volution represents the body chamber. It is incomplete aperturally, but flares somewhat adorally which suggests that very little of it is missing. No test remains, but a series of low, sinuous, transverse ribs is preserved on the body chamber. These ribs form prominent, U-shaped sinuses ventrally, and broad, asymmetrical salients ventrolaterally and laterally.

The second of the two specimens is an incomplete and somewhat distorted internal mold, preserved in pyrite. In all measurable properties, it is precisely similar to the first specimen described. In this specimen, however, portions of the inner whorls are exposed, and they compare in size and detail with Remelé's illustrations of the type of *T. hospes*. The ventral annulations are more prominent on this specimen, and this prominence seems to increase slightly on the inner whorls.

Remarks: The specimens at hand are almost precisely like the types of *Trocholites hospes* (Remelé), hence there is no doubt as to their specific identity. There is, however, some question as to the generic reference, as a glance at the synonymy will disclose. The relatively large size, strongly gibbous form of the conch, and widely flaring lateral margins of the peristome set this species apart from the more typically discoidal *Trocholites*, and these morphological differences were considered by both Remelé and Foerste to be more than specific significance. A majority of writers, however, follow Schröder in referring the species to *Trocholites* (with which it has much in common) and that practice is followed here, albeit with some reservations. That is, although there is considerable variation in conch shape and size within the known early Middle Ordovician species of *Trocholites*, only one other (*T. ruedemanni* Flower) resembles *T. hospes* in gibbosity, and only one of its contemporaries (*T. macrostoma* Schröder) approaches it in size. Furthermore, its whorls are more deeply impressed and much more rapidly expanding than are those of any other species of the genus heretofore described.

Distribution: In Norway, *Trocholites hospes* appears to be confined to the Cephalopod shale, the two known representatives having been collected from that horizon at Melbostad (Hadeland district) and at Hovindsholm, Helgøya (Nes—Hamar district).

GENUS *Discoceras* Barrande, 1867.
Type species: Clymenia antiquissima Eichwald, 1840.

Conch with $3^1/_2$ to 5 fairly slowly expanding, generally depressed volutions which are impressed dorsally and characterized by a reniform, trapezoidal, or subquadrangular cross-section. Body chamber one-quarter to one-half volution or more in length, in most species free from preceding whorl adorally, and in some species, contracted immediately apicad of aperture. Umbilicus perforate, but diameter of perforation small. Chambers typically short, septa shallow, sutures forming ventral, lateral, and dorsal lobes and ventrolateral and dorsolateral saddles. Shell surface marked by adapically imbricate lamellae which form ventral and dorsal sinuses and asymmetrical lateral salients, the chords of which are strongly oblique to the sutures. In more advanced (or more specialized) forms, shell is periodically constricted, giving rise to a series of more or less pronounced annulations or "ribs" which are parallel to the growth-lamellae.

Siphuncle central in initial half-volution, marginodorsal in succeeding $1^1/_2$ to 2 whorls, then separating from dorsum to greater or lesser degreee in outer volutions. As shown in text-figure 15A, the septal necks are short, loxochoanitic to orthochoanitic in structure; connecting rings thickened in their mid-portions, but thinning adapically and adorally in each camera. Organic cameral deposits not known.

Mutvei (1957, p. 237, 239, p. 8, fig. 1—5; pl. 9, fig. 1—3) has recently described impressions in the body chambers of two specimens of *Discoceras*, one referred by him to *D. angulatum* (Saemann) and the other identified only as *D.* sp. In both of these specimens, the so-called "annular elevation" (slightly raised, sinuous, transverse band of shell material near the adapical end of the body chamber) is similar in that the broad area to which the retractor muscles were functionally attached occupies a ventral position (rather than a lateral position, as in *Nautilus*, or a dorsal position, as in *Lyceoceras*, *Orthoceros*, *Baltoceras*, *Lituites*, etc.). In Mutvei's specimen of *D. angulatum*, the areas of functional retractor attachment are marked by low, elliptical bosses of shell material which extend considerably orad on the venter beyond narrow, sinuous, in part tuberculate ridges which mark the functional areas of attachment of the mantle and subepithelial musculature, respectively. In the specimen described as *D.* sp. (which is similar, at least in whorl outline, to *D. ievesense* (Balaschov)) the annular elevation bears no ventral bosses, but its adoral edge is produced into a ridge which swings orad on the venter and bears a shallow, V-shaped, adapically-directed recess in the mid-ventral line. Presumably, this recess corresponds to the narrow, longitudinal trough which separates the ventral bosses of *D. angulatum*, and marks the point of separation, at least adorally, between the right and left retractor muscle complexes.

Remarks: Representatives of *D. antiquissimum* (Eichwald) are not uncommon in the Gastropod limestone (5a) of the Oslo Region, and the above description (largely adapted from Strand, 1933, p. 32—33) is based primarily upon these specimens. In addition, a well preserved specimen of the type species was sectioned in a plane parallel with the siphuncle (*see* figures 1, 2 on Plate 11), and data concerning its structure have been derived from this specimen. In this connection, it should also be mentioned that similar sections have been prepared from a representative of *Discoceras roemeri* Strand, and for many of the species from the Middle Ordovician of the Oslo Region described below. In all of these, the structure and position of the siphuncle is qualitatively the same at corresponding growth stages, which indicates that a compact and closely knit generic group is involved.

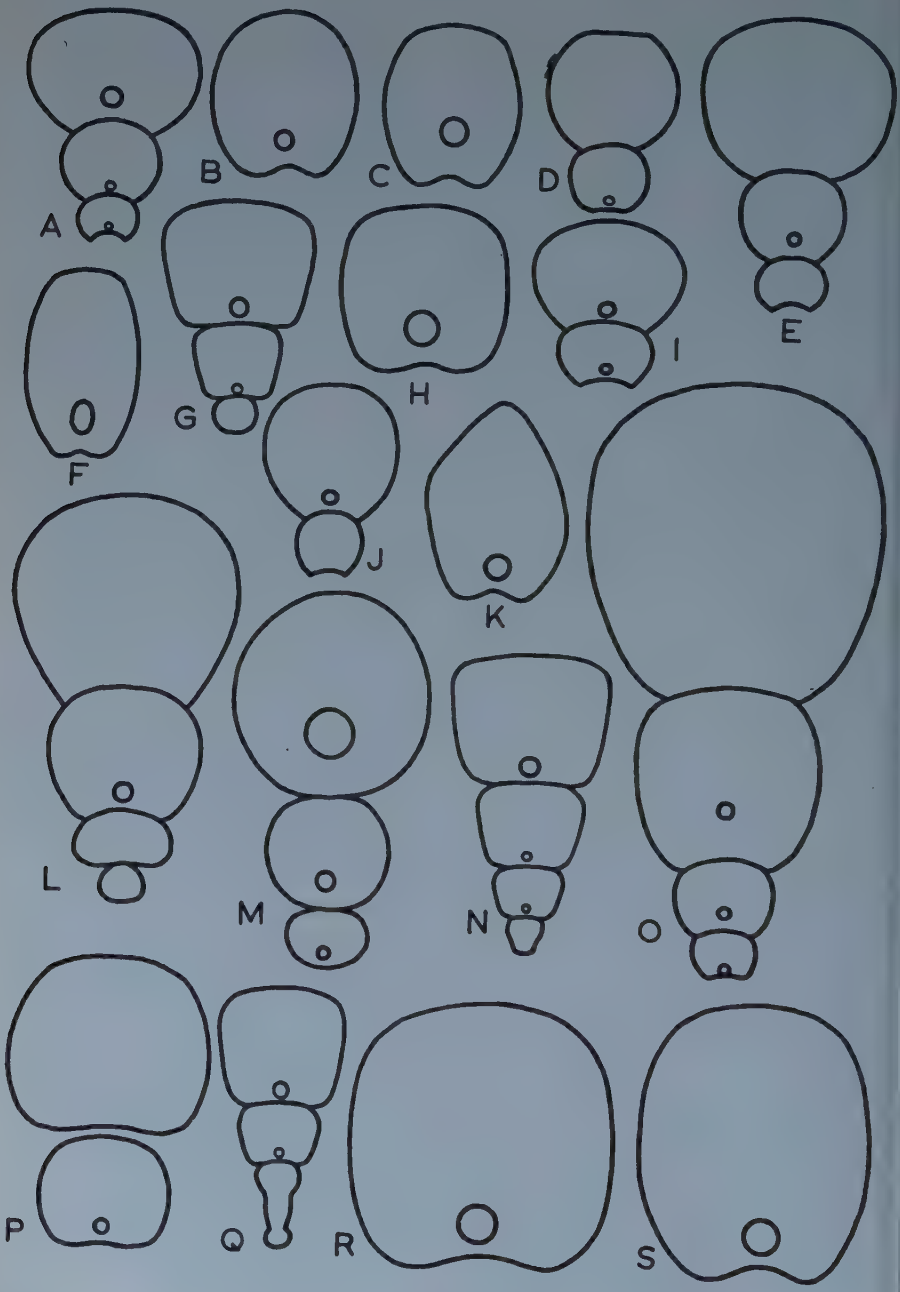
A great majority of the species of *Discoceras* heretofore described have been referred at one time or another to *Schroederoceras* Hyatt, as have a number of others (*e.g.*, *Curtoceras teres* (Eichwald), *Estonioceras lamellosum* (Hisinger), etc.) which are now known to belong in neither *Discoceras* nor *Schroederoceras*. Hyatt (1894, p. 458—460) erected *Schroedoceras* for 11 species of Middle and Upper Ordovician nautilicones, mostly European, which he realized were close to *Discoceras*, but differed primarily from that genus in having less prominent ornamentation, or annulations developed only on the inner whorls. Most of his generic diagnosis, however, consists of a comparison between *Schroederoceras* and *Trocholites*, and there is no question but that these two are distinct both externally and internally. After studying representatives of the types of both genera, Strand (1933, p. 32) concluded that there was no significant difference between

S. angulatum (Saemann), the type of *Schroederoceras*, and *D. antiquissimum* (Eichwald), the type of *Discoceras*, hence treated *Schroederoceras* as a junior subjective synonym of *Discoceras*. The name *Schroederoceras* was retained by Ulrich, *et al.* (1942, p. 79—80), who regarded the "... subquadrangular cross section of its whorls" to be one of its most distinctive characters, and, apparently, the only one sufficiently important to be specifically mentioned. Flower & Kummel (1950, p. 613) follow Strand in suppressing *Schroederoceras*, but Balaschov (1953b, p. 250—251) has recently described most of the trocholitids from the Ordovician of the Russian Platform in terms of *Schroederoceras*, apparently restricting *Discoceras* so that it is doubtful if any but the type species would be retained in it.

I have been able to study only a plaster cast of the type of *Schroederoceras angulatum* (Saemann), but careful comparisons of sections from closely related forms from the Gastropod limestone convince me that the supposedly significant variations in whorl outline, length of body chamber, and prominence of annulations all occur in a group of species which are so closely similar internally as to be essentially indistinguishable. Annulation appears to be initiated on the innermost whorls of the older species but to be absent or poorly defined on the outer whorls of those forms. It is only in a few of the later species that annulation is a marked feature of all whorls, which suggests that its appearance is proterogenetic, as it seems to be, for example, in a large number of Mesozoic ammonoids. If there were any reasons to believe that *Schroederoceras angulatum* represented either the smooth, ancestral stock or the derived annulated group, I would favor retention of the name. However, it represents only an intermediate form (as do several other species) and I can distinguish no clearly defined specific groups on any of the several morphological bases enumerated above. Consequently, I am in complete agreement with Strand who regarded all of these species as members of a single generic group, for which *Discoceras* is the oldest available name.

Discoceras is distinguished from the several Lower Ordovician representatives of the Trocholitidae in that its conch is larger, sometimes compressed, and typically more prominently ornamented. These differences are, however, difficult to quantify, and it is probable that longitudinal sections through the siphuncle would exhibit more diagnostic intergeneric features. Such sections have been illustrated only for *Curtoceras* (Ulrich, *et al.*, 1942, p. 71, fig. 18; p. 72, fig. 19; p. 73, fig. 20, 21; pl. 39, fig. 2; pl. 50, fig. 1—4) hence comparison of these presumably more characteristic internal structures is difficult except with that genus. In *Curtoceras*, the siphuncle is distinctly ventral in position in the first camera, subcentral in the remainder of the first volution, and subdorsal (but never marginal) in all succeeding volutions. *Curtoceras* also occurs in the Lower and Middle Ordovician of the Scando-Baltic province (Balaschov, 1953b, p. 245—250), and Holm's (1885, pl. 5, fig. 5,6) illustrations (but not Schindewolf's, 1942, p. 351, fig. 5e) of one of these species (*Curtoceras teres* (Eichwald)) are essentially similar to the ones of the type species, *C. eatoni* (Whitfield), given by Ulrich *et al.* (1942, *loc. cit.*).

With the exception of a questionable specimen reported by Thomas & Teichert (1947, p. 50—51) from the Lower Ordovician of Bendigo, Victoria, Australia, and a specimen described (as *D.* aff. *D. canadense* (Whiteaves)) by Miller *et al.* (1954, p. 116—117, pl. 58, fig. 7; text-fig. 17) from Baffin Island, *Discoceras* is apparently restricted to rocks of Middle and Upper Ordovician age in the Scando-Baltic province. It should be noted, however, that a specimen, from Spiti, in the central Himalaya, referred to *Trocholites juliformis* Salter by Reed (1912, p. 80, pl. 12, fig. 4) and specimens from the Ordovician of Yun-nan, China, placed by the same author (Reed, 1917, p. 37, pl.6, fig. 4, 4a—b, 5—5a) in *Trocholites yunnanensis* Reed have the subquadrate, depressed whorls and large marginodorsal siphuncles characteristic of *Discoceras* and may properly belong in that genus. On the other hand, it is improbable that the types of *D. canadense* (Whiteaves), from the arctic Upper Ordovician of Manitoba, belong in *Discoceras*. They are not dorsally impressed and their surface sculpture, while broadly similar in pattern, is not much like that of *Discoceras* in detail. Miller *et al.*'s *Discoceras?* sp. from Silliman's Fossil Mount, Baffin Island, is so poorly preserved and anomalous that it seems unwise to list it as a representative of *Discoceras*. Their "*D.* aff. *D. canadense* (Whiteaves)", however, seems to be typical of the genus and, furthermore, is closely similar in whorl outline and size to *D. fleischeri*, n. sp., from the uppermost Middle Ordovician of the Oslo Region. Teichert's (1937, p. 85—86, pl. 17, fig. 4, 5) *Discoceras* sp., from Mt. Nautilus, Baffin Island, is much like the specimen illustrated by Miller and his colleagues, and may be conspecific.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Discoceras arctuatum (Lossen).

Plate 12, figure 4; ?Plate 8, figure 7; text-figure 13J.

1860. *Lituites arcuatus* LOSSEN, Zeitschr. d. deutsch. geol. Ges., Bd. 12, p. 25.

Type data: This species was originally based upon two specimens from the Toten district of the Oslo Region. One of these is illustrated here for the first time, but it is probable that both of them, originally stored in the Museum für Naturkunde in Berlin, were destroyed when that institution was bombed during World War II. Before the war, however, Professor Trygve Strand studied and prepared an illustration of one of these specimens, and it is primarily from his unpublished notes that the following diagnosis and description are drawn.

Diagnosis: Mature conch consisting of slightly more than 3¾ volutions, with a maximum diameter (measured across the umbilicus) of about 100 mm. Body chamber free from preceding volution, and widely divergent. Whorls essentially as broad as high, broadly rounded ventrally, flattened laterally, and only slightly impressed dorsally. Surface sculpture consisting of closely spaced lirae, 1 to 3 mm distant, which form lateral and ventral sinuses. Camerae short, about 4.5 in a distance equivalent to the conch diameter at the adoral end of the series measured. Sutures form shallow dorsal, ventral, and lateral lobes. Siphuncle dorsal and submarginal in position at end of third volution.

Fig. 13. *Discoceras* Barrande. Diagrammatic transverse sections of (A) *D. damesi* (Schröder); (B) *D. varospira* (Eichwald); (C) *D. gubkovense* (Balaschov); (D) *D. angulatum* (Saemann); (E) *D. fleischeri*, n. sp.; (F) *D. danckelmanni* (Remelé); (G) *D. hyatti* Strand; (H) *D. ievesense* (Balaschov); (I) *D. depressum*, n. sp.; (J) *D. arcuatum* (Lossen); (K) *D. vasalemmense* (Balaschov); (L) *D.* aff. *canadense* (Whiteaves) Miller, Youngquist, & Collinson; (M) *D. bandonis* Remelé; (N) *D. saemanni* (Hyatt); (O) *D. boreale*, n. sp.; (P) *D. roemeri* Strand; (Q) *D. antiquissimum* (Eichwald); (R) *D. wesenbergense* (Balaschov); (S) *D. tammikuense* (Balaschov). D, G, N, P, and Q, after Strand, 1933, x0.65. B, C, H, K, R, and S, after Balaschov, 1953, x1. L, after Miller, *et al.*, 1954, x1. F, and M, after Remelé, 1890, x1. All others are original, x1.

Description: The specimen upon which the above diagnosis is based is an internal mold of the adapical 3 volutions of the conch to which is attached an incomplete external mold of an additional three-fourths volution. The adoral end of the outer whorl is separated from the preceding volution by a distance of 10 mm. At the end of the third volution, the height and width of the camerae are 17 mm, the maximum width occurring at mid-height. The venter is broadly arched, the sides flat, and the dorsum slightly impressed, the width of the impressed zone being about 9 mm. Surface sculpture is preserved on the external mold, and consists of adapically imbricating lamellae, 1 to 3 mm distant, between which occur fine, parallel growth-lines. Lamellae and growth-lines are oblique and somewhat convex adorally on the sides, but form a broad, rounded hyponomic sinus ventrally. Siphuncle is near, but not in actual contact with the dorsum, its diameter at the end of 3 volutions being about 2 mm.

A second specimen, from the Cephalopod shale on Helgøya, probably represents *D. arctuatum,* but it is so incomplete that it can not be referred to that species with certainty. This specimen (figure 7 on Plate 8) is an external mold of the apical 3 volutions of a rather slowly expanding conch, 71 mm in diameter. Several sutures are exposed on the sides of the innermost volutions; these form shallow lobes in those places, and their spacing indicates that, in that part of the conch, about 3.5 camerae occupied a length equal to the lateral diameter of the whorl. Surface sculpture consists of a pattern of growth-lamellae similar to that exhibited by the type of *D. arcuatum* described in the immediately preceding paragraphs.

Remarks: Although no certain representatives of *D. arcuatum* occur in collections I am studying, Lossen's and Strand's remarks concerning the forms upon which it is based indicate that it is a distinct species, differing from contemporaneous representatives of *Discoceras* in whorl outline, in having a widely divergent body chamber, and having finer and more closely spaced growth-lamellae.

Distribution: The two original types were collected by Leopold von Buch at Billerud in the Toten district. Presumably they came from the Cephalopod shale, as does the fragmentary external mold tentatively referred here to this same species.

Discoceras boreale Sweet, n. sp.

Plate 8, figures 4, 6; Plate 9, figures 1, 2; Plate 10, figure 2, 3, 4, 5, 7; Plate 11, figure 4; text-figure 13 O.

Name: The name, *boreale,* is derived from the Latin signifying North, or northern.

Type data: Holotype, an essentially complete internal mold (P.M.O. 61428) from the Cephalopod shale at Hovindsholm, Helgøya (Nes—Hamar district).

Material: This new species is represented in collections at hand by some 25 specimens, some of which are partially testiferous internal molds of various portions of the conch; others are external molds.

Diagnosis: A large species of *Discoceras* with a conch about 150 mm in over-all diameter at maturity, and consisting of 4 slightly impressed volutions, the inner 2 of which are depressed, the outer ones somewhat higher than wide. Text-figure 13 0, based on the holotype, shows the shape of the volutions at various stages in conch growth. Camerae are shallow and short, 5—7 occuring in a length equivalent to the maximum diameter of the volution at the adoral end of the series measured. Sutures form dorsal, lateral, and very slight mid-ventral lobes. Body chamber less than one-fourth volution in length and only slightly separated from the preceding whorl at its adoral end. Siphuncle slightly ventrad of center in first camera, marginodorsal from end of first volution to beginning of second, and between 7 and 10 mm from dorsum in outermost whorl. Siphuncular structure orthochoanitic, with short straight septal necks and thick, tubular connecting rings.

Shell ornamentation consists of a series of adapically imbricate lamellae, each from 2 to 3 mm long and containing 7 to 10 growth-lines. The adoral edges of these lamellae form well marked ridges which swing adapically on the sides and form broad, rounded sinuses on the venter. There is also a more widely spaced series of low annulations which is parallel to the growth-lamellae but most prominently developed in the adapical volutions.

Remarks: This species includes a majority of the many specimens of *Discoceras* occurring in the Cephalopod shale of the Oslo Region. The above diagnosis is based largely upon the holotype, but it would not be modified in any significant way by a consideration or detailed description of the other available representatives of the species, which are clearly conspecific with it. There is, as might be expected, some slight variation in relative cameral length and in general conch proportions. As a rule, the camerae are more variable in the adapical than in the adoral parts of the conch, but this variation is within rather small limits, as the specific diagnosis indicates. There is considerably more variation in the prominence (but not in the kind) of surface sculpture. It seems unwise to attribute great significance to this, however, for much of it is undoubtedly due to post-mortem breakage or weathering of the shell.

Discoceras boreale is distinguished from previously recognized, essentially contemporaneous species of *Discoceras* such as *D. damesi* (Schröder), *D. arcuatum* (Lossen) and *D. bandonis* Remelé, by its large size, closely spaced camerae, maturely compressed volutions, and rather prominent ornamentation.

Distribution: Representatives of this species are most common in the Cephalopod shale of the Nes—Hamar district, but they are also found at that horizon in the Toten district. A single specimen from Slottsbakken, Oslo belongs in *D. boreale*, and it probably came from the Ampyx limestone (4aβ). Two additional representatives were collected on Lindøya, in the Oslofjord, by Gerhard Holm, but the labels which accompany them give no stratigraphic information.

Discoceras boreale amplicameratum Sweet, n. subsp.

Plate 11, figure 3.

Name: The subspecific name refers to the relatively long camerae which distinguish the subspecies from the typical species.

Type data: The holotype, P.M.O. 69308, is a fragmentary internal mold of a portion of one of the outer volutions of the conch. It was collected from the Ampyx limestone (4aβ), at Fornebo airport, Oslo (Oslo—Asker district.)

Material: In addition to the holotype, 2 other specimens appear to be referable to this new subspecies. One of them, P.M.O. I 0262, comes from an exposure of the Ampyx limestone between Arnestadstrand and Asker (Oslo—Asker district); the other (P.M.O. I 030) was collected on Ildjernet, an island in the Oslofjord.

Diagnosis: Like *D. boreale*, n. sp., but with somewhat broader adoral cross-section, relatively longer camerae, (3.5 to 4 in a length equivalent to the maximum diameter of the volution) and more prominent annulations on the adoral part of the conch.

Description: The most complete representative of this subspecies, the holotype, is an internal mold of half a volution of the phragmocone of a large conch, the over-all diameter of which exceeded 100 mm, the maximum transverse diameter of the specimen. There are slightly less than four camerae in a distance equal to the maximum diameter of the conch at its adoral end. The whorl cross-section is subquadrate, the height being somewhat greater than the width. Sutures form dorsal, lateral, and ventral lobes, the latter being very broad and shallow. The surface of the test is ornamented in a fashion similar to that of *D. boreale s. s.*, but the annulations show prominently on the internal mold, which is not the case in comparable parts of the typical species.

Remarks: All of the specimens referred to this subspecies came from rocks which may well be essentially equivalent in age to (or only slightly younger than) the Cephalopod shale of the Nes—Hamar district, which yielded a majority of the specimens of *D. boreale*. The features which distinguish *D. boreale amplicameratum* from the typical *D. boreale*, are all differences of degree, which suggests that the animal itself was undoubtedly very similar to the typical species. It is possible that the slight differences in whorl shape, cameral length, and prominence of ornamentation are a result of either provincial isolation, slight differences in age, or both. They do not seem to be great enough, however, to warrant referring the Ampyx limestone specimens to a separate species.

Distribution: All three specimens are from the Ampyx limestone (4aβ) in the Oslo—Asker district.

Discoceras depressum Sweet, n. sp.

Plate 12, figure 5; text-figure 13 I

Name: The specific name, *depressum*, refers to the fact that the whorls of this species are depressed, that is, wider than high.

Type data: The holotype (P.M.O. 69290) is a somewhat distorted internal mold of an essentially complete conch. It was collected at Helsvær, Østre gravlund (Oslo—Asker district), presumably from some part of the Ogygiocaris shale.

Material: Two specimens, both internal molds, the most nearly complete being the holotype, the second numbered P.M.O. 69291. Both came from the same locality and almost certainly from essentially the same horizon.

Diagnosis: A moderately large species of *Discoceras*, in which the volutions are broadly depressed, having a height to width ratio of about 3:5. Test prominently ornamented by sinuous growth lamellae but apparently not annulated in adult stages.

Descriptions: The holotype is the somewhat distorted internal mold of an essentially complete nautiliconic conch, 92 mm across, which is composed of 4 moderately expanded volutions. The body chamber occupies the adoral third of the outermost volution; its apertural end has been crushed, but it appears to have been slightly separated from the venter of the penultimate whorl for a short distance adorally. In cross-section, the whorls are broadly depressed, with a ratio between height and width of about 3:5. The venter is broadly arched (but not flat), the sides are rounded, and the dorsum impressed. However, the impressed zone is very shallow even in the adapical whorls. The maximum whorl width occurs distinctly ventrad of mid-height, or at a point about one-third the distance from venter to dorsum. The camerae are short, 4 occurring in a length equivalent to the lateral diameter of the conch at that place. Sutures are sinuous as a result of the whorl outline, and form broad, shallow ventral, lateral, and dorsal lobes, separated by somewhat more narrowly rounded ventrolateral and dorsolateral saddles.

Portions of the replaced test adhere to the ventral side of the body chamber, and to the sides of the innermost volutions. These indicate that the test was ornamented in a fashion similar to other species of *Discoceras*, that is, by a series of adapically imbricate growth-lamellae, the adoral edges of which form lirae which are oblique to the sutures, are convex orad laterally, and form rather deep, rounded sinuses on the venter. Apparently, these lirae were originally most prominent adorally.

The siphuncle is large, and only slightly separated from the venter at the adoral end of the phragmocone. As in other species of *Discoceras* it is orthochoanitic, with short, straight or loxochoanitic septal necks and thickened connecting rings.

The single paratype is similar to the holotype, but it is smaller and represents only the adapical 2½ volutions of the conch. It indicates, however, that the siphuncle became separated from the dorsal margin of the conch at the end of about 1½ volutions, and that the umbilicus is perforate. The diameter of the perforation is less than half a millimeter. In addition, this specimen preserves an external mold of the test, from which it can be seen that, adapically, the growth-bands were short, and their adoral edges formed fine lirae of equal prominence.

Remarks: This species differs from other contemporaneous forms, and from a majority of the known species of *Discoceras* regardless of age, in the possession of whorls which are considerably depressed, even at maturity. *Discoceras damesi* (Schröder) is apparently similar in that it has depressed whorls through at least the third volution. However, that species was based on a fragment which provides an excellent example of the surface sculpture and immature cross-section, but gives no information concerning the camerae or sutures. It differs from *D. depressum* in that the cross-section is elliptical rather than subtrapezoidal, its volutions expand more rapidly, and the ornamentation appears to be somewhat coarser adapically. *Trocholites yunnanensis* Reed, from the Middle Ordovician of Yun-nan province in China, resembles *D. depressum* in most comparable features, particularly in whorl outline. The internal structures of Reed's species are unknown, however, hence it is not completely certain that it belongs in *Discoceras*.

Distribution: The holotype and paratype of this species both came from Helsvær, Østre gravlund, in Oslo. They were collected many years ago, however, by an amateur paleontologist, and are not accompanied by any stratigraphic information. Other specimens from the same locality suggest that the rocks which yielded the collection belong in the Ogygiocaris shale, hence the types of *D. depressum* are provisionally ascribed to that horizon in this report.

Discoceras fleischeri Sweet, n. sp.

Plate 12, figure 1; text-figure 13E.

Name: The specific name, *fleischeri*, is proposed in honor of Mr. W. Fleischer, an employee of the Norsk Hydro Company, who collected the holotype.

Type data: The holotype, P.M.O. 69292, is an adorally incomplete internal mold which was found at Kjørholt limestone quarry near Brevik (Langesund—Gjerpen district) and was probably derived from the Encrinite limestone.

Material: In addition to the holotype, the collections at hand contain 1 specimen (P.M.O. 69293) from virtually the same stratigraphic horizon within the Oslo Region. This is so similar to the holotype of *D. fleischeri* that it is being assigned to it with no question.

Diagnosis: A species of *Discoceras* characterized by its relatively small size, depressed volutions, large siphuncle, and prominent adapical annulations.

Descriptions: The holotype of this species is an adorally incomplete, partially testiferous internal mold representing about 3½ whorls of a subdiscoidal nautiliconic conch, the over-all diameter of which is 69 mm. The outermost volution is non-septate, and presumably represents the body chamber. The volutions are depressed in cross-section, the height being rather uniformly four-fifths the width. As shown in text-figure 13E, the venter is broadly and gently convex; the sides are rounded, convex, and converge dorsally; the dorsum is very shallowly impressed, and its width is slightly less than half the maximum width of the whorl. The maximum width of the volution is located at a point one-third the way between the venter and the dorsum. In the inner 3 volutions there are 3 camerae in a ventral distance equivalent to the lateral diameter of the conch. As the camerae do not become noticeably shorter at the adoral end of the phragmocone, it is presumed that the specimen is immature. Sutures form dorsal, lateral, and very faint ventral lobes, narrowly rounded dorsolateral saddles, and broad asymmetrical ventrolateral saddles.

The internal structures of the conch have been almost completely destroyed by recrystallization, but the siphuncle is exposed at two places in the penultimate whorl. At these places, which are about half a volution apart, the siphuncle is circular in section, about 2 mm in diameter, and located 1.5 to 2 mm from the dorsal side of the conch.

Recrystallized fragments of the test, exposing both outer and inner layers, adhere to the left side of the phragmocone and the ventral side of the body chamber. From these fragments it is clear that the test was ornamented by a series of sinuous growth-bands which form asymmetrical lateral salients and deep, broadly U-shaped ventral sinuses. At intervals of 3 to 4 mm, these bands form ridges on the test surface which are prominent laterally but somewhat less conspicuous ventrally. In the adapical volutions, a series of faint lateral annulations appears on the mold, corresponding in position to the ridges of the outer shell surface. No such annulations are discernible, however, on the adoral volution.

A single specimen (P.M.O. 69293) from the Gagnum shale at Mjør, Gran (in the Hadeland district) also seems to belong in *D. fleischeri*. This specimen is an almost completely testiferous internal mold, some 61 mm in over-all diameter, which represents 3 to 3½ volutions of a nautiliconic conch. The volutions are depressed, four-fifths as high as wide, and only moderately expanding orad. The structure of the conch interior can not be determined, but the siphuncle is exposed at the adapical end of the outer volution. At this place, it is 2 mm in diameter and virtually marginal in position. The surface sculpture of the outer volution is like that of the holotype, but the lateral ribs are not as prominent. However, like the holotype, the inner volutions appear to be faintly annulated.

Remarks: Discoceras fleischeri is, as might be expected, very closely related to the several species of *Discoceras* described by Strand (1933) from the Upper Ordovician of the Oslo Region, and particularly to *D. roemeri* Strand. In all of these species, however, the whorl cross-section is subquadrate in shape, and in *D. roemeri*, the dorsal side of the body chamber is slightly wider than the venter. It might also be noted that the specimen from Silliman's Fossil Mount, Baffin Island, described by Miller, *et al.* (1954, p. 116—117, pl. 58, fig. 7; text-figure 17) as *D.* aff. *D. canadense* (Whiteaves) has a cross-sectional shape and pattern of ornamentation closely similar to *D. fleischeri* (*see* text-figure 13L) and may be closely related to or conspecific with the Norwegian species. The strata which yielded the Baffin Island specimen are regarded by Miller and his colleagues as of "early Upper Ordovician" age, and the Upper Chasmops and Encrinite limestones of the Oslo Region, although presumably somewhat older than the typical North American Upper Ordovician, may be of much the same age as the Baffin Island shales.

Distribution: Representatives of this species occur in the Encrinite limestone of the Langesund—Gjerpen district, in the Upper Chasmops limestone of the Oslo—Asker district, and in the Gagnum shale which forms essentially the same horizon in the northern part of the Hadeland district.

Discoceras ievesense (Balaschov).

Plate 12, figures 2, 3; text-figure 13H.

1953. *Schroederoceras ievesense* BALASCHOV, Trudy V.N.E.G.R.I., n. ser., no. 78, p. 259—260, pl. 9, fig. 1a—c.

Material: Six specimens, all incomplete, from the Lower Chasmops limestone (P.M.O. I 2412, I 0357—59, I 0353, I 1767, I 1766) of the Oslo—Asker district and from the Cyclocrinus beds (P.M.O. I 1741) of the Nes—Hamar district are referred to this species without question. Two others (P.M.O. I 0378, and I 1436 (= 34414)), one from the Lower Chasmops limestone and the other from the Cyclocrinus beds, are included here tentatively.

Descriptions: The most nearly complete of the several specimens at hand (figure 2 on Plate 12) is an internal mold of the conch, from which it is clear that the mature individual had an over-all diameter of about 110 mm, and consisted of nearly 4 rather rapidly expanding whorls which are subquadrate in cross-section and about as high as wide. The body chamber is somewhat compressed adorally, occupies the outermost quarter volution, and does not appear to have diverged from the preceding whorl for any appreciable part of its length, if at all. The camerae are short, about 5½ occurring in a distance equal to the diameter of the conch at the adoral end of the series measured. Sutures are sinuous, forming broad, rounded lobes on the flattened venter and sides, and in the shallow dorsal impressed zone. These lobes are separated ventrolaterally and dorsolaterally by narrow, rounded saddles. The surface of the test is marked by rather coarse lirae formed by the adoral edges of short, adapically imbricate growth-lamellae, and a series of broad, faint annulations parallel to the growth-bands. Both growth-bands and annulations are oblique to the sutures and broadly convex adorally on the sides. They form deep, U-shaped sinuses on the venter. The annulations vary in prominence adorally, but are more closely spaced and distinct adapically.

The siphuncle is large, and located 2 to 4 mm from the dorsum at the adoral end of the phragmocone. As in other species of *Discoceras*, it is composed of short, orthochoanitic septal necks and thick, tubular connecting rings.

The remaining five specimens which certainly belong in this species are similar in all comparable respects to the one just described. They differ from it, and from the holotype, in being somewhat distorted and fragmentary. Only one of these (P.M.O. I 0358) is illustrated.

Remarks: Although there is some minor variation exhibited, in the aggregate the specimens at hand are so similar to the illustrated types of *Discoceras ievesense* (Balaschov) that there is little doubt but that they belong in that species (or in one so closely similar morphologically as to be indistinguishable from it). The holotype, from the Jôhvi limestone (D_I) of Estonia, is presumably somewhat younger than the Norwegian specimens, but its subquadrate whorl cross-section, large siphuncle, and rather rapid adoral expansion are so characteristic that, even though the forms at hand are probably older, they are placed in the species without question.

Distribution: Lower Chasmops limestone on Bygdøy, Snarøya, Lindøya, and perhaps on Steilene Fyr (all in the Oslo—Asker district); Cyclocrinus beds at Furuberget (Nes—Hamar district) and perhaps also at Tangen, Gjøvik (Toten district). In Estonia representatives of this species are reported only from the Jôhvi limestone.

Discoceras rarospira (Eichwald).

Plate 17, figure 6; text-figure 13B.

1860. *Clymenia rarospira* EICHWALD, Lethaea Rossica, Text, v. 1, pt. 2, p. 378, pl. 29, fig. 2a—b [*not* pl. 29, fig. 1a—b, or 6a—c].
1870. *Lituites rarospira* BARRANDE, Distrib. des Céphalopodes, etc., p. 61.
1894. *Schroederoceras rarospira* HYATT, Am. Philos. Soc., Proc., v. 32, p. 467.
1953. *Schroederoceras rarospira* BALASCHOV, Trudy V.N.E.G.R.I., n. ser., no. 78, p. 251—252, pl. 6. fig. 4a—b.

Material: A single specimen, P.M.O. I 2142, probably from the Lower Chasmops limestone of the Oslo—Asker district.

Description: The single representative of this species in collections at hand is 84 mm in over-all diameter and represents 3 or 3½ whorls of a subdiscoidal phragmocone. The body chamber and an indeterminate length of phragmocone are missing adorally. The whorls are compressed, slightly impressed dorsally, and subovate in outline. At the adoral end of the otuer volution, lateral and dorsoventral diameters are 24 and 26 mm respectively. There are 3½ to 4 camerae in a distance (measured along the venter) equivalent to the lateral diameter of the conch. The septa are shallow; the sutures form slight ventral and lateral saddles. In the outer volution, the siphuncle is 5 mm in diameter and located 2 mm from the dorsal margin of the conch.

The surface of the test is marked, on the outer volution, by a series of fine, closely spaced growth-lines which represent the adoral edges of thin, adapically imbricate shell-bands. In addition to these, there is a more widely spaced, but rather irregular series of low annulations. Both growth-lines and annulations form deep, rounded ventral sinuses and asymmetrical lateral salients.

Remarks: This specimen differs from the holotype of *Discoceras rarospira* (Eichwald) only in having somewhat shorter camerae (*i.e.*, 3½ to 4 rather than 3 in a ventral distance equivalent to the lateral diameter of the conch). Furthermore, it almost certainly comes from strata essentially equivalent in age to those from which Eichwald's specimens were collected. The specimen is of additional interest for it shows that, during the animal's lifetime, a colony of bryozoans apparently grew on the ventral surface of the conch and was progressively covered as conch growth continued. Remnants of this colony now occur between the outer two volutions. This suggests that the animal was most probably sluggish; certainly even such a small incrustation would inhibit its agility as a swimmer, and it is doubtful if such a colony would have been established on the shell of a very highly mobile animal.

Distribution: The single Norwegian representative of this species now known probably came from the Lower Chasmops limestone at Blakstadtangen in the Oslo—Asker district. Balaschov (1953a, p. 212) has reported it from C_I (Aseri-Lasnamäe-Uhaku limestones) of Estonia and with question from D_2, the Keila limestone. However, Kaljo, *et al.* (1956, p. 39) list it only from the Idavere (C_{III}) of Estonia.

FAMILY Lituitidae Phillips, 1848[1].

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[1] The designation "Lituidae", proposed by Noetling in 1884 (and corrected to "Lituitidae" by Schröder in 1891), has long been considered the oldest available formal name for the family typified by *Lituites*. The same name, however, was formally employed and diagnosed by Phillips (Phillips, J., 1848, The Malvern Hills, compared with the Palaeozoic districts of Abberley, Woolhope, May Hill, Tortworth, and Usk. Geol. Surv. Great Britain, Mem., v. 2, pt. 1, p. 246, 250) some 36 years before Noetling used it, and Phillips (rather than Noetling) must then be regarded as the author of Lituitidae. In this connection it should also be mentioned that the name "Lituidae" was proposed by Gray (1847, Zool. Soc. London, Proc., pt. 15, p. 206) for a family of living cephalopods typified by *Lituus* Brown, 1756 (which Gray believed to be the oldest available name for *Spirula* Lamarck, 1801). Although Gray's "Lituidae" (which is properly compounded) is based on a genus which may have no status, it may have to be retained. It does not, however, constitute a preoccupation of Noetling's "Lituidae", as Remelé (1890, p. 99, footnote 1) believed, for Noetling's spelling is in error, and the apparent homonymy results from this. Fortunately, neither Gray's nor Noetling's names have any effect on the status of Lituitidae Phillips.

Orthochoanitic nautiloids with shells consisting of a compressed adapical tarphyceraconic, gyroceraconic, or cyrtoceraconic stage followed adorally by an orthoceraconic or somewhat sigmoidally curved portion which is typically subcircular in cross-section. The late mature peristome is characterized by two, three, four, or five lobate or narrowly produced, linguiform lappets. The test is marked by sinuous, transverse growth-lines and, in some species, a parallel series of annulations, the salients and sinuses of which correspond in position, at least adorally, to the lappets and emarginations of the peristome. The siphuncle is ventral and marginal in position at the apex of the conch, but becomes central or subdorsal in the first few camerae. In subsequent camerae, its position may be central or even slightly ventrad of the center. In *Rhynchorthoceras*, however, the siphuncle appears to be ventrad of the center at all stages of growth. The siphuncle is orthochoanitic. The septal necks are rather long and essentially straight; the connecting rings are distinctly laminated, although not prominently thickened as in many Lower Ordovician genera. In at least two, and probably in all lituitid genera, the connecting ring is slit, perforated, or otherwise incomplete ventrally near mid-length of each camera. This perforation appears to have been formed by resorption of part of the connecting ring, but there is no unequivocal evidence to make this a certain conclusion.

Cameral deposits of a distinctive nature have been described (Holm, 1885, p. 21—24, pl. 3, fig. 2a—c; pl. 4, fig. 1—20: Remelé, 1890, p. 65, fig. 41; p. 70, fig. 42; p. 72, fig. 43; p. 74, fig. 44; Schindewolf, 1942, p. 348) in species belonging in *Lituites*, *Ancistroceras*, and *Rhynchorthoceras*. In all of these species, there are thick episeptal and hyposeptal deposits in each camera, the diagonal junction of which forms a transversely crenulated, conical surface ("pseudoseptum") with its truncated apex at the septal foramen. The deposits are continuous laterally and ventrally, but they do not meet dorsally, leaving on that side wedge-shaped spaces. In the episeptal deposits this space contracts adapically and peripherally, whereas in the hyposeptal deposits it appears to contract only toward the center of the conch. Subsequent to the formation of the epi-, and hyposeptal deposits, additional, but distinctly different deposits were formed within the dorsal hiatus. These deposits form a longitudinal, dorsal wall (the "vertical lamella" of authors) the laminae of which bend around the connecting rings of the siphuncle in such a fashion as to form a subcentral, dumb-bell, or hour-glass-shaped pillar. Near cameral mid-length, the laminae curve into the siphuncle through the slit or perforation in the connecting ring, and, in that way, become continuous with more or less irregular, but nevertheless laminated endosiphuncular deposits. As is true in other nautiloids having comparable structures, the cameral deposits of the lituitids are delayed in their development so that, as a rule, they are thick adapically but thin or absent in the adoral camerae of the phragmocone. Holm's (*loc. cit.*) excellent illustrations of these deposits in *Ancistroceras* show, as do several specimens of *Rhynchorthoceras* in the collections at hand, that, although the hiatus in the cameral deposits is typically mid-dorsal in position, it may be laterally deflected in a few camerae to produce a "vertical lamella" that is distinctly offset when traced the length of the specimen. It should also be noted that Remelé (*loc. cit.*) figures dendritic impressions in the adoral surfaces of episeptal deposits in *Lituites perfectus* and *L. lasaulxii*. These are of a type reminiscent of those in *Leurocycloceras* cf. *niagarense*, which are thought by Flower (1941a, p. 482—488) to represent impressions of the vascular system in a supposed "cameral mantle".

The annular elevation, or area of muscle attachment, has been described in *Lituites procerus* Remelé (Noetling, 1882, pl. 11, fig. 5) and its configuration in *Rhynchorthoceras helgoeyense*, n. sp., is suggested by a structure shown in text-figure 14B and in figure 9 on Plate 4. Schröder (1881, p. 60) has also suggested that a faint line near the adapical end of the body chamber in the holotype of *Rhynchorthoceras zaddachi* Remelé may represent the annular elevation in that species, but his description of it, and Remelé's illustrations (1890, pl. 6, fig. 5a, 5b) of the same specimen do not permit comment on the correctness of this interpretation.

In *Lituites procerus*, the annular elevation is divisible into two subparallel parts, a relatively wide adoral annulus (conchial zone I of Mutvei, 1957, p. 224) and a narrow, ridge-like adapical annulus (conchial zone II of Mutvei). Conchial zone I consists of a slightly raised annular ridge which is distinguishable from conchial zone II

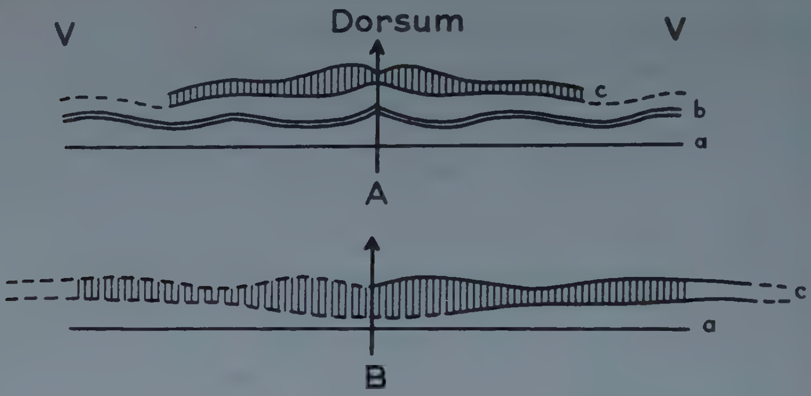

Fig. 14. Diagrammatic representations of the annular elevations of (A) *Lituites procerus* Remelé after (Noetling, 1882) and (B) *Rhynchorthoceras helgoeyense*, n sp., x0.5. "a", the adoral suture; "b", conchial zone II; "c", conchial zone I.

only laterally and dorsally. The two zones are apparently confluent ventrally. On the sides, zone I separates from zone II, and widens dorsad, attaining its greatest width dorsally. In the dorsal mid-line, zone I is constricted in width in such a fashion that it forms two transversely, but imperfectly elliptical areas, which were presumably the loci of attachment for the retractor musculature. Zone II is represented by a low, annular ridge which, at least laterally and dorsally, is parallel to the adapical margin of zone I.

In *Rhynchorthoceras helgoeyense*, n. sp., a faint, incomplete impression, similar to that of conchial zone I in Noetling's specimen of *Lituites procerus*, occurs at the adapical end of the body chamber. The elliptical areas of retractor attachment are only slightly wider than the lateral extension of conchial zone I, but, as in *L. procerus*, they are dorsal in position and apparently separated from one another by only a slight mid-dorsal constriction in width.

At the present time, the Family Lituitidae includes eight Ordovician genera (*Lituites*, *Angelinoceras*, *Cyclolituites*, *Holmiceras*, *Ancistroceras*, *Rhynchorthoceras*, *Tyrioceras*, and *Trilacinoceras*, n. gen.). The Silurian *Ophidioceras* may belong here (Flower, *in* Flower & Kummel, 1950, p. 614), but, if so, its relationships are obscure. *Holmiceras*, *Ancistroceras*, and *Rhynchorthoceras* have all been reported from the Upper part of the Lower Ordovician (Vaginatum limestone of

Öland, Kunda limestone of Estonia, Asaphus shale or Endoceras limestone of the Oslo Region, Norway) although the references (Rüdiger, 1889, p. 80: Schindewolf, 1942, p. 348—349) to *Rhynchorthoceras* in rocks this old are probably in error. That is, I have been unable to locate any description of, or reference to, such an occurrence other than by Rüdiger and Schindewolf, and it seems probable that the latter based his remarks on the former's catalogue, in which a large number of typically Middle Ordovician species are ascribed to the Vaginatenkalk. Rüdiger's error in doing this seems apparent when the stratigraphic comments of the species' authors are consulted.

Numerous lituitids are found in the Platyurus, Schroeteri, and Crassicauda limestones (which, in the order listed, succeed the Vaginatum limestone in Sweden), in the Ogygiocaris and lower Chasmops series of the Oslo Region, and in the Lasnamäe and Uhaku limestones of Estonia. In later Ordovician rocks, however, lituitids are not common. A *Tyrioceras?* occurs in collections from the Lower Chasmops limestone of the Oslo Region, and several generically indeterminate forms have been found in the Upper Chasmops limestone (*see* Strand, 1933, p. 51—52, who included descriptions of some of these specimens in his Upper Ordovician study). Balaschov (1953a, p. 213) has reported, but has not yet described or figured, a new species of *Tyrioceras* from zone D_I of the Russian platform, and the type species of that genus is from the Upper Ordovician Tretaspis limestone in the Oslo Region. Undoubted lituitids also occur in an undescribed fauna from the Boda limestone of the Siljan district in Sweden, which is probably equivalent in age to the Norwegian Gastropod limestone (*i. e.*, uppermost Ordovician).

As is clear from the preceding discussion, the Lituitidae are known best from, and appear to be restricted largely to the Scando-Baltic Ordovician. Numerous specimens from other parts of the world have at one time or another, been placed in *Lituites*, but, insofar as I have been able to determine, the great majority of these belong in other genera and other families. No lituitids are known from North America, nor from the widespread arctic Ordovician cephalopod faunas. Harrington & Leanza (1957, p. 35) report *Lituites* sp. from the upper Llanvirnian *Proetiella tellecheai* zone of western Argentina, and Reed (1917, p. 38—39, pl. 6, fig. 7, 7a) has described a representative of

Lituites from Ordovician strata at Shih-tien, in southwestern Yun-nan, China. However, his illustration of this specimen, which is part of the adapical whorl, indicates that it lacks the prominent annulations which ordinarily mark this part of the conch in *Lituites*, and his description of it states that "... the surface of the shell ... is encircled by rather strong concentric equidistant striae ...", which again suggests that, if the specimen is, indeed, a *Lituites*, it is certainly not a "typical" representative of the genus. This specimen of doubtful affinities is probably the one Balaschov (1953b, p. 230—231) had in mind when he included China in the geographic range of *Lituites*.

In 1942 (p. 346—350), Schindewolf suggested that coiling in the Lituitidae developed proterogenetically and that the ancestors of this family are to be found in the group of straight nautiloids he terms "Orthoceracea". It seems probable, however, that his conclusions were based on faulty stratigraphic information, and, in addition, he does not seem to have attached any great significance to the internal features of the conch. Flower (*in* Flower & Kummel, 1950, p. 614) placed the Lituitidae in his Order Barrandeoceratida, and, in at least one subsequent paper (1954, chart, p. 35) indicates his belief that the family was derived from the Barrandeoceratidae. In 1955c, however, this same writer stated (p. 251) that "... in spite of marked structural differences in the wall of the siphuncle, it now appears that the Tarphyceratidae are the ancestors of a group of coiled shells which persisted throughout the Ordovician and Silurian. Most remarkable among these forms is the family Lituitidae ...". As Flower was concerned only with the general problems of coiling in fossil nautiloids, his 1955c statements were neither amplified nor explained. Quite independently, and in connection with the present studies, I have arrived at essentially the same conclusion. That is, for the reasons enumerated in the several paragraphs immediately below, it appears most logical to believe that the Lituitidae represent a rather bizarre and specialized group of nautiloids stemming not from the straight "Orthoceracea" nor the coiled Barrandeoceratidae, but from either the Tarphyceratidae or Trocholitidae — both of which are closely related and constitute the nucleus of the Suborder Tarphyceratina.

The oldest known lituitids, both referable to *Holmiceras* Hyatt, are coiled adapically, and the apparent absence in Lower Ordovician

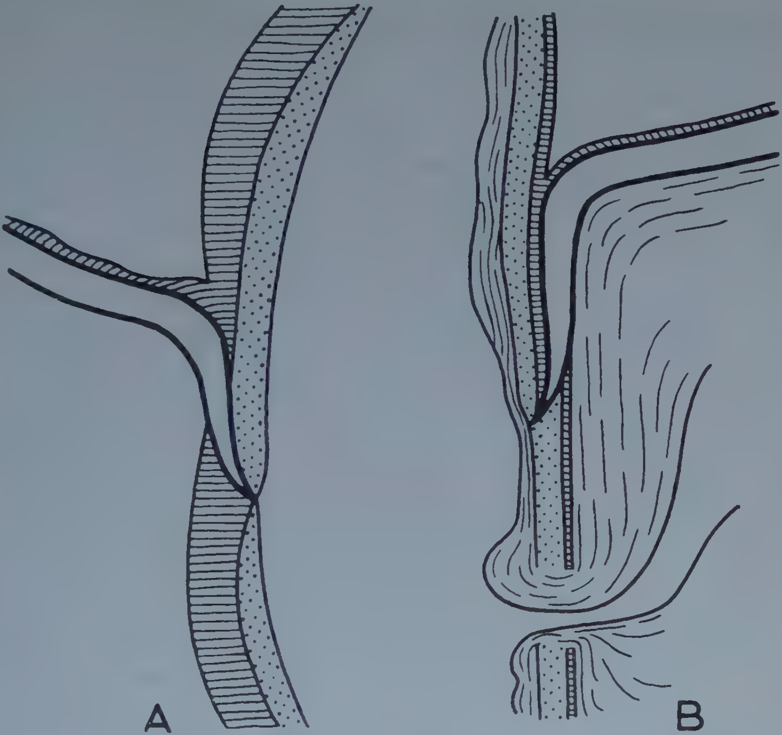

Fig. 15. Greatly enlarged, somewhat schematic view of the ectosiphuncle of (A) *Discoceras boreale*, n. sp., and (B) *Rhynchorthoceras helgoeyense*, n. sp. Presumably comparable structures are shown by the same symbols in both diagrams, and the relationship between endosiphuncular and cameral deposits in *R. helgoeyense* is shown in (B). (*Compare* also figure 4, Plate 11, and figure 3, Plate 20).

rocks in the Scando-Baltic region or elsewhere of similarly ornamented straight or cyrtoceraconic forms casts doubt upon Schindewolf's hypothesis that the Lituitidae developed from such an ancestor through the addition of proterogenetic coiling (although it is distinctly possible that the family exhibits proterogenesis in other features). On the contrary, the stratigraphic evidence, even though it is far from satisfactory or complete, indicates that the ancestral group was coiled rather than straight.

The ectosiphuncle of those lituitids available to me for study is complex, at least in the larger parts of the phragmocone. The connecting rings are clearly differentiated into two structurally distinct laminae (*see* text-figure 15B) which, although not unduly thickened are almost precisely comparable in arrangement and appearance to those of *Discoceras* (*compare* text-figure 15A). In addition, it appears likely that a portion of the connecting ring was resorbed after the entire structure had been formed, giving the siphuncular tissues access to the camerae. This suggests that the Lituitidae (or at least those forms in which the siphuncular and cameral structures are known) developed from a group in which cameral tissues had disappeared or lost their function, and that the deposits, like the shell from, were developed independently and not inherited as a pattern from the ancestral group.

Holm's (1897b, pl. 9, fig. 1—3) illustrations of the adapical portion of *Lituites perfectus* Wahlenberg, indicate that the siphuncle is primitively ventral or subventral in position, but that it migrates dorsad very rapidly as coiling of the conch proceeds. This is true also in at least some of the genera now included in the Trocholitidae, and, to a lesser extent, is found also in the Tarphyceratidae.

These several lines of reasoning, taken together, suggest that the ancestors of the Lituitidae had a coiled conch in which the siphuncle moved dorsad from a primitively subventral location and was composed of long, straight septal necks and connecting rings differentiated into well defined layers. It is also probable that the ancestral stock was characterized by a somewhat compressed conch and had a well developed hyponomic funnel and, therefore, a relatively prominent hyponomic sinus on the ventral side of the peristome.

These postulated conditions are all fulfilled by the Trocholitidae, and, to a somewhat lesser degree, by the Tarphyceratidae as well. In both of these families, gyroceraconic or late-maturely uncoiled conchs are also found. Furthermore, both of these groups reached the acme of their development, diversity, and distribution in the Arenig (or Upper Canadian), near the end of which epoch the first lituitids seem to have made their appearance.

One rather distinct, but probably superficial morphological difference separates the lituitids from the tarphyceratinids. That is, the loci of retractor muscle attachment in the latter group are ventral in position, whereas in the lituitids they are dorsal. I am inclined to suspect, however, that this apparently striking difference is to be regarded as little more than a reflection of disparities in conch shape, which, in turn, suggests that the tarphyceratinids and lituitids, although otherwise closely related, were adapted to different environments, living habits, or both. I can think of no other part of the animal's anatomy which would be as delicately sensitive, for purely mechanical reasons, to a change in habits or shell form as would be the musculature involved in retracting or adjusting the cephalopodium. Mutvei (1957, p. 231—232) has shown that known muscle-attachment patterns can be referred to one of three general groups: one in which the retractor scars are ventral, another in which they are lateral, and a third in which they are dorsal. The first includes primitive, coiled nautiloids like *Estonioceras*, *Planctoceras*, and *Discoceras;* the second includes *Nautilus* and other coiled shells which are deeply involute; and the third is composed of shells which are essentially straight at maturity. It seems to me quite probable that if, for example, a group 1 species gave rise to a group 3 form, there would be little likelihood of the group 1 muscle pattern remaining unaltered in the derived species. It is rather more likely that a majority of nautiloids with group 3 shell form, regardless of their ancestry, would show group 3 muscle patterns, or variations of them. This is little more than a reaffirmation of the rather widely held belief that gross conch form in nautiloid cephalopods is an adaptive feature and one in which a great deal of convergent homeomorphy is to be expected.

Even though the ancestry of the Lituitidae seems to be rather clear, it is difficult to recognize evolutionary patterns or clear phylogenetic relationships within the group itself. Solutions to these problems are complicated at the present time not only by the generally incomplete preservation of the lituitids, but also by a lack of definitive stratigraphic information concerning the distribution of the several genera and species which constitute the family. Although certain broad generalizations are suggested by the facts now available, a morphological study of carefully made stratigraphic assemblages will be needed to provide more detailed information.

The peculiarly uncoiled shell is perhaps the most striking character of the Lituitidae as a whole. Its gross form, however, exhibits considerable plasticity, even on the specific level, and does not for that reason, appear to be a particularly reliable or useful guide to general phylogeny. On the other hand, the rather striking patterns formed by the growth-lines, together with apparently systematic ontogenetic modifications in these patterns, seem to be more useful in suggesting relationships.

Although *Holmiceras, Ancistroceras,* and *Angelinoceras* are somewhat different in gross conch shape, their growth-lines show a similar ontogenetic sequence in patterns and modifications, and there can be little doubt but that these three genera are very closely related. That is, growth-lines in early portions of the conch are characterized by ventral, lateral, and dorsal sinuses. During growth, the ventral and dorsal sinuses tend to be reduced and, in at least *Holmiceras* and *Ancistroceras,* are replaced at maturity by broad salients.

The same tendencies are exhibited by some (but not by all) species of *Rhynchorthoceras,* which, however, has a cyrtoceraconic conch and may well include at present the cyrtoceraconic form-derivatives of several species of *Ancistroceras.* The position of *Tyrioceras* is not clear because it is separated from the major group of described lituitids by a considerable stratigraphic interval and nothing is known of its early stages. It may be related, however, to the *Holmiceras-Ancistroceras* group.

Lituites, Cyclolituites, and *Trilacinoceras* are also closely related and their somewhat later stratigraphic appearance suggests that the group they represent was derived from the more primitive *Holmiceras-Ancistroceras* stock. Typical *Lituites* is characterized by prominent ventral and lateral growth-line sinuses throughout growth, and by a broad dorsal sinus which is subdivided by a low salient except, perhaps, in the very earliest parts of the conch. At maturity, the salients which separate the growth-line sinuses are elaborately produced to form five prominent lappets in all known species. In this respect, then, the growth-line sequence of *Lituites* very closely resembles that developed in the early parts of the *Holmiceras* and *Ancistroceras* conch.

Lituites törnquisti Holm deviates from this general pattern in that it has ventral and lateral (but no dorsal) emarginations in the early growth-lines, a shallow dorsal sinus in somewhat later stages, and the elaborate five-lappeted *Lituites* peristome only at maturity. The three-lobed growth-line pattern is carried completely to maturity in

Trilacinoceras discors (Holm) and a transition from *L. törnquisti* to *T. discors* is found in *T. norvegicum*, n. sp., which is not only intermediate in age, but develops slight secondary dorsolateral salients in the peristome at late maturity. It thus seems highly likely that *Trilacinoceras* developed from *Lituites* through *L. törnquisti*.

Cyclolituites does not uncoil to any appreciable extent, but it has a pattern of growth-lines and an elaborate five-lappeted mature peristome very similar to those of *Lituites*. It seems probable, therefore, that *Cyclolituites* is little more than a specialized form-derivative of *Lituites*, modified in size and shape as an adaptation to some restricted or otherwise specialized ecological niche.

The several developmental sequences indicated in the preceding paragraphs very strongly suggest that modifications in the growth-line patterns of the lituitids appeared proterogenetically. The early four-, or five-lobed pattern of the *Holmiceras-Ancistroceras* lineage seems to have been established throughout the conch and highly elaborated in *Lituites*, and the maturely three-lappeted peristome of *Trilacinoceras* is heralded in the early (rather than in the late) stages of *Lituites törnquisti*. The gaps which separate the genera and species cited above are, in many cases, considerable, and it is possible that, as more detailed collections are made and studied, other phylogenetic schemes will appear to be more practical. Nevertheless, on the basis of information presently available, the relationships indicated seem to be the most plausible.

GENUS *Holmiceras* Hyatt, 1894.

Type species: Lituites praecurrens Holm, 1891.

Conch lituiticonic, either slightly compressed or somewhat depressed, with adapical spiral composed of one to one and a half loosely coiled volutions and a relatively short adoral uncoiled portion which is sigmoidal in longitudinal profile and expands rather rapidly orad of the apical spiral. Camerae relatively short, septa only slightly concave. Sutures essentially straight adapically, but adorally they form broad, shallow ventral and (in the type species) dorsal lobes. Growth-lines and annulations form ventral, lateral, and dorsal sinuses and ventrolateral and dorsolateral salients in the early parts of the conch, but adorally, the ventral and dorsal sinuses disappear so that, on the body chamber, the venter and dorsum are occupied by broad salients. In the adoral portion of the phragmocone the siphuncle is circular in section and located slightly dorsad of the center. Nothing is known of its position or structure in earlier parts of the conch, but presumably it is similar in both respects to other lituitids.

Remarks: Holmiceras is clearly rather closely related to *Ancistroceras*, from which it differs primarily in having an open (or gyroceraconic) spiral and an uncoiled segment which has a sigmoidal (rather than straight) longitudinal profile. In both *Holmiceras* and *Ancistroceras*, the ventral and dorsal growth-line sinuses are reduced orad, and there can be but little doubt that at maturity the apertural margins in both genera were essentially alike.

At the present time, only two species can be referred to *Holmiceras*. These species are both Lower Ordovician in age, and were apparently essentially contemporaneous, *H. praecurrens* (Holm) being known only from the Gray Vaginatum limestone of Öland (Holm, 1891, p. 761), and *H. kjerulfi* (Brøgger) from the Orthoceras limestone (*s. l.*) of the Oslo Region, Norway (Brøgger, 1882, p. 54, pl. 12, fig. 16). The strong morphological similarity between *Holmiceras* and *Ancistroceras*, together with the fact that *Holmiceras* seems to precede *Ancistroceras* stratigraphically, suggest that the former gave rise to the latter. It should also be pointed out that the early stages of *Holmiceras* (and also of *Ancistroceras*) are somewhat more elaborately duplicated in the more specialized lituitids *Angelinoceras*, *Lituites*, *Cyclolituites*, and *Trilacinoceras*. In the latter genera, however, characters typical of the early parts of *Holmiceras* and *Ancistroceras* are carried into the mature conch, which suggests that the prominently sculptured peristome of the more advanced forms is a feature introduced proterogenetically, and that the simpler peristome indicated by the late stages of *Holmiceras* and *Ancistroceras* is the primitive (rather than either an advanced or specialized) condition.

Holmiceras kjerulfi (Brøgger).

Plate 4, figures 2, 3 and 4.

1882. *Lituites kjerulfi* BRØGGER, Die silurischen Etagen 2 und 3 im Kristianiagebiet und auf Eker, etc., p. 54, pl. 12, fig. 16.

Type data: Lectotype, and only known representative, and incomplete internal mold preserved in coarse-grained, light buff limestone. P.M.O. I 006.

Description: The lectotype and only known specimen of this species is an incomplete internal mold, 54 mm long, which represents 17 camerae of a lituiticonic phragmocone and includes the adoral quarter volution of the adapical spiral and the adjacent part of the uncoiled adoral portion. Reconstruction of the adapical part of the conch suggests that the over-all diameter of the coiled portion (measured parallel to the axis of the uncoiled segment) can not have greatly exceeded 15 mm, and the small diameter of the adapical end of the specimen suggests that the coiled part probably consisted of no more than one gyroceraconic volution. Throughout that part preserved, the conch is slightly compressed and the venter somewhat flattened. In the uncoiled segment, the dorso-ventral diameter of the conch increases by 1 mm in every 5 mm of length.

The camerae are relatively longer adapically than adorally. In the adapical portion of the specimen, 3 camerae occupy a distance equivalent to the dorso-ventral diameter of the conch, whereas in the adoral portion, 4 camerae occupy a similar distance. Adapically, the sutures are straight and directly transverse to the long axis of the conch. Adorally, however, they become progressively more sinuous, developing broad, shallow ventral lobes, ventrolateral saddles, shallow lateral lobes, and broad, only slightly arched dorsal saddles.

The siphuncle is exposed in transverse section at the adoral end of the specimen. At this place it is circular in section, 2 mm in diameter, and located slightly dorsad of the center of the conch.

Remarks: Although the lectotype of *H. kjerulfi* is neither as nearly complete nor as well preserved as the type of *H. praecurrens*, the type of *Holmiceras*, it is very closely similar to it. *H. praecurrens* expands more rapidly than *H. kjerulfi* (1 mm in 3 mm, rather than 1 mm in

5 mm), is more closely camerated (6 camerae in a distance equal to the conch diameter, rather than 3 or 4), and, at least adorally, is depressed in cross-section, rather than slightly compressed. The type species also exhibits a very slight dorsal lobe in the sutures, whereas the Norwegian species has a broad, nearly flat saddle in that position.

Distribution: The only known representative of *Holmiceras kjerulfi* is from either the upper part of the Asaphus shale (3cβ) or the lower part of the immediately overlying Endoceras limestone (3cγ), at Slemmestad in the Oslo—Asker district. Both of these horizons are, of course, considered to be uppermost Lower Ordovician in Age.

GENUS *Ancistroceras* Boll, 1857.
[= *Strombolituites* Remelé, 1881].

Type species: Ancistroceras undulatum Boll, 1857.

Conch lituiticonic, composed of 1½ to 2 contiguous or only slightly separated adapical whorls followed adorally by a long, rather rapidly expanding orthoceraconic portion. The whorls of the enrolled segment are laterally compressed and the umbilicus is perforate. The orthoceraconic segment expands at an angle of about 30°, is essentially circular in cross-section, and succeeds the enrolled part without forming the elongate sigmoidal ventral profile typical of *Lituites*. Conch surface marked by sinuous growth-bands and annulations which form five salients adapically, three, and finally two adorally, at least in some species. Peristome of mature conch with broad dorsal and ventral salients and shallow lateral emarginations.

Ancistroceras is most closely related to *Holmiceras*, from which it differs in having small, tightly coiled whorls and a somewhat more rapidly expanding conch. Mature portions of the conch are difficult to distinguish from some species of *Rhynchorthoceras*, but typical representatives of that genus seem to be somewhat less rapidly expanding.

The oldest reported representatives of *Ancistroceras* come from the uppermost Gigas (= Vaginatum) limestone on Öland (Bohlin, 1955, p. 128), and the youngest from the Ampyx limestone of the Oslo Region, which is probably only slightly younger than the upper part of the Crassicauda (= Ancistroceras) limestone of Öland.

Ancistroceras undulatum Boll, 1857.

Plate 13, figures 2, 3, and 5.

Lituites (*Ancistroceras*) *undulatum* BOLL, 1857, Archiv d. Verein des Freunde der Naturgesch. in Mecklenburg, Jahrg. 11, p. 87, pl. 8, fig. 25a—c.
Ancistroceras undulatum DEWITZ, 1880, Zeitschr. d. deutsch. geol. Ges., Bd. 32, p. 387: — — — NOETLING, 1884, Kgl. Preuss. geol. Landesanst., Jhrb. f. 1883, p. 132—135, pl. 18, fig. 7, 7a: — — — HOLM, 1885, Paleont. Abh. v. Dames & Kayser, Bd. 3, Hft. 1, p. 21—24, pl. 3, fig. 2a, 2b, 2c; pl. 4, fig. 1, 3, 4—20: — — — RÜDIGER, 1889, Ueber die Silur-cephalopoden aus den mecklenburgischen Diluvialgeschieben, p. 44—45: — — — HOLM, 1891, Geol. Fören. i Stockholm, Förh., bd. 13, p. 38: — — — PATRUNKEY, 1926, Zeitschr. f. geschiebeforsch., Bd. 2, p. 120, 121: — — — FOERSTE, 1929, Denison Univ. Bull., Jour. Sci. Labs., v. 24, p. 272—275, pl. 41, fig. 1A, 1B, 3A, 3B, 4A, 4B, 4C; pl. 42, fig. 3, 4: — — — BALASCHOV, 1953, Trudy V.N.E.G.R.I., n. ser., no. 78, p. 236—238, pl. 14, fig. 5a, 5b, 6, 7.
Strombolituites undulatum REMELÉ, 1881, Zeitschr. d. deutsch. geol. Ges., Bd. 33, p. 191, fig. 1: — — — REMELÉ, 1882, ibid., Bd. 34, p. 117—119, pl. 5, fig. 1.

Material: Three fragmentary specimens (P.M.O. I 0196, I 0374, 58910) representing various parts of the phragmocone.

Descriptions: The specimen illustrated in figure 2 on Plate 13 is the adapical coiled portion of *Ancistroceras undulatum*, to which only the adapical 17 mm of the uncoiled, orthoceraconic segment is attached. The coiled portion has a diameter of 10 mm, and consists of 1½—2 tightly coiled volutions. The umbilicus can not be seen. The uncoiled portion expands at the rate of 1:2, or at an angle of about 30°. Growth-bands and annulations mark the external surface of this fragmentary specimen: they form ventrolateral, dorsolateral, and dorsal salients, the latter of which is bounded dorsolaterally by slight sinuses.

The largest of the three specimens here referred to *Ancistroceras undulatum* Boll is the one represented by figure 5 on Plate 13. This specimen is 128 mm long, essentially circular in cross-section, and about 64 mm in diameter at its adoral end. The interior is very coarsely recrystallized, but faint outlines of one septum and a subcircular, tubular structure at the adoral end indicate that the specimen represents only part of a much larger phragmocone which expanded rather rapidly and had an essentially subcentral siphuncle. The rate of conch expansion is about 1 in 3, which indicates an apical angle of somewhat less than 30°. Growth-bands and annulations are well preserved in the dorsal, ventral, and right lateral zones, and form deep, broadly U-shaped ventral sinuses, symmetrically rounded ventrolateral salients, broad, shallow lateral sinuses, and faint salients in the dorsolateral and dorsal zones. Adorally, the dorsolateral and dorsal salients blend so that in that part of the conch the dorsum and the dorsolateral zones are occupied by a single broad,, gently arched salient.

A third specimen, in which only the ventral and ventrolateral portions of the adapical part of the phragmocone are exposed, is shown in figure 3 on Plate 13. This specimen is 94 mm long, expands at the rate of about 1: 2.5, and shows a sequence of growth-band and annulation patterns similar to those exhibited more completely on the larger form described above.

Distribution: In Norway, certain representatives of *Ancistroceras undulatum* Boll are known only from the Ampyx limestone (4aβ) in the Oslo—Asker district. A large number of specimens, described below as *A. undulatum* Boll?, occur in the Cephalopod shale of the Nes—Hamar district, which, in its upper parts, at least, may be of about the same age as the Ampyx limestone.

Ancistroceras undulatum Boll?

Plate 18, figure 1.

Material: In addition to the specimens of *Ancistroceras undulatum* described above, the collections at hand contain ten specimens which undoubtedly belong in *Ancistroceras*, and may well be referable to *A. undulatum* Boll. None of these can be identified with certainty, however, nor do the majority of them merit illustration or extended description. Brief mention of several of these specimens is included here because they represent parts of the conch not previously known.

Description: Two of the specimens (R.M. MO 88048, MO 88093) to which I refer, are adapical portions of a straight phragmocone in general similar to *A. undulatum;* five (P.M.O. I 2368, 69294, 69296, I 1552—3, I 1438) represent the fragmentary adoral portions of conchs which attain rather large diameters (62, 67, 70, 95, and 112 mm), expand rather slowly (ca. 1: 6), and have annulations which form broad ventral salients, shallow ventrolateral sinuses, and broad, flat dorsal salients. The largest of these, that is, the one with a diameter of 112 mm, is also the largest representative of *Ancistroceras* heretofore reported.

One of the specimens at hand (P.M.O. 69294), shown in figure 1 on Plate 18, is 135 mm long, circular in section, 95 mm in diameter, and preserves an essentially complete mature peristome. This structure corresponds precisely in configuration to the adoral growth-band pattern. That is, it shows broad dorsal and ventral salients and ventrolateral emarginations. Furthermore, the peristome is preceded adapically by a broad contracted zone, which presumably indicates that the mature shell margin was considerably thickened.

Two specimens, probably from the Ampyx limestone (4aβ), also belong in *Ancistroceras*, perhaps in *A. undulatum*. One of these (P.M.O. I 1712) is similar to the large, slowly expanding forms described above, whereas the other (P.M.O. 3806—7), which seems to be only a body chamber, is smaller in diameter (61 mm adorally; 48 mm adapically) and expands at the rate of 1: 5. Growth-bands on both specimens form well marked ventral sinuses, ventrolateral salients, lateral sinuses, dorsolateral salients, and dorsal sinuses, the prominence of which may be due, in part, to compression.

Distribution: Eight of the ten specimens referred to above come from the Cephalopod shale at Hovindsholm, Helgøya (Nes—Hamar district) and two of them (from Løken, Bygdøy, and Håkavikodden, respectively, in the Oslo—Asker district) were probably collected from the Ampyx limestone (4aβ).

GENUS *Angelinoceras* Hyatt, 1894.

Type species: (herein designated) *Lituites latus* Angelin, 1880.

Conch lituiticonic, with relatively large, compressed, loosely coiled adapical spiral, and a rather rapidly expanding, somewhat compressed uncoiled segment, which has a sigmoidal ventral outline in its adapical portion. Growth-lines and annulations, insofar as they are known, form deep ventral sinuses, prominent ventrolateral salients, broad, asymmetrical lateral sinuses, low dorsolateral salients, and a broad, nearly straight dorsal sinus which is subdivided, at least in the early stages, by a mid-dorsal salient. Expands more rapidly and has larger coiled portion than *Lituites;* expands less rapidly, and has adapical whorls markedly distinct (in size and loose-coiling) from *Ancistroceras.*

In his original discussion of *Angelinoceras*, Hyatt (1894, p. 508—509) mentions only two species, *Lituites latus* Angelin and *Lituites anguinus* Angelin. Neither was cited as type, nor, to the best of my knowledge, has either been designated as such subesquently. The two cited species are very different, their types are not particularly well preserved, and, after a study of both specimens, I can see no very good reason for uniting them in the same genus. Consequently, since Hyatt's generic concept of *Angelinoceras* seems to have been based largely upon *Lituites latus* Angelin, that species is here designated the type of *Angelinoceras. Lituites anguinus* seems, properly, to belong in *Lituites* Bertrand, rather than in *Angelinoceras*, which, based on *L. latus*, is quite different in form.

Angelinoceras latum (Angelin), the only previously described species of this little-known genus, is apparently restricted to the lower part of the Platyurus limestone of Sweden. The genus seems, however, to be represented in the Ampyx limestone (4aβ) of the Oslo Region by an incomplete specimen which can not be diagnosed specifically. This suggests that *Angelinoceras* has a rather extended range in the early Middle Ordovician of the Scando-Baltic province, although the genus does not seem to be particularly common.

Angelinoceras sp.

Text-figure 16.

Material: A single, fragmentary internal mold, P.M.O. I 027—8.

Description: The only representative of *Angelinoceras* in the collections at hand is an internal mold, 82 mm long, which represents the adapical spiral, 37 mm in diameter, and the early part of the uncoiled, orthoceraconic portion of the phragmocone, 45 mm long. The coil consists of about 2 volutions, which expand rather gradually and are not in contact with each other. The straight portion joins the apical coil with a noticeable increase in diameter, but with no marked sigmoid curvature on the venter. This segment expands from a diameter of about 15 mm at its proximal end, to 18 mm at the adoral end of the specimen, indicating a growth-coefficient of about 1:15. No growth-lines or annulations are preserved.

Remarks: The coiled portion of the conch in the specimen just described compares almost exactly with a similar part of the type of *Angelinoceras latum* (Angelin). However, *A. latum* expands adorally at the rate of about 1:4, and, in this respect, the two are considerably different. The fact that the Norwegian specimen comes from rocks which are considerable younger than those yielding typical *A. latum* suggests that it represents a distinct species. It is, however, too poorly preserved to be diagnosed completely and a proper delimitation of the undescribed species to which it may belong is not now possible.

Distribution: Ampyx limestone (4aβ), Ildjernet (Oslo—Asker district).

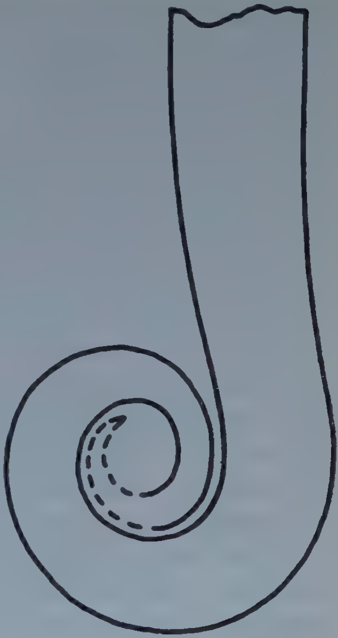

Fig. 16. *Angelinoceras* sp. Outline diagram, x1, of a specimen (P.M.O. I 027—28) from the Ampyx limestone (4aβ) at Ildjernet (Oslo—Asker district.)

GENUS *Rhynchorthoceras* Remelé, 1882.

Type species: (designated by Foerste, 1929) *Rhynchorthoceras beyrichi* Remelé, 1882.

Conch a longiconic cyrtoceracone which is slightly curved in its adapical portion but essentially straight for most of its length. Camerae vary in length, but sutures are invariably simple and directly transverse to the long axis of the conch. Body chamber may be nearly half the length of the conch and, in known species, it expands somewhat less rapidly than does the phragmocone. Siphuncle large in size, central or ventro-central in position, and orthochoanitic in structure, being composed of rather long, straight septal necks and laminated connecting rings. Camerae occupied, at least in the adapical portions of the conch, by heavy epi-, and hyposeptal deposits, the disposition and detailed structure of which is apparently like that found in other lituitids (*see* family diagnosis above). Surface of test marked by sinuous growth-bands which form ventrolateral and dorsal salients and lateral and, in most forms, slight ventral sinuses. Peristome unknown except in two specimens herein referred to *R. helgoeyense*, n. sp. In these specimens, the peristome has an outline corresponding to the configuration of the growth-bands on the body chamber and adoral parts of the phragmocone.

To the best of my knowledge, only three species of *Rhynchorthoceras* have been reported (Remelé, 1882, p. 134: Lindström, 1888, p. 11: Jaanusson & Mutvei, 1953, p. 19) from strata in place. These species, *R. oelandicum* Remelé, *R. tenuistriatum* Remelé, and *R. angelini* (Boll), are recorded, respectively, from the Upper Gray Orthoceras limestone of Öland, the Upper Red Orthoceras limestone of Sweden, and from the upper part of the Platyurus limestone (zone with *Illaenus* aff. *sulcifrons*) in the Siljan district, Sweden. It is probable that the latter two occurrences represent essentially the same stratigraphic horizon. All but one (*R. oelandicum*) of Remelé's species were based on specimens from drift boulders, but the reported lithology and fossil content of these boulders suggest the Upper Red and Gray Orthoceras limestones of Sweden, or, in more modern terms, the Platyurus, and Schroeteri-Crassicauda limestones. Rüdiger (1889, p. 80) ascribes all of Remelé's species to the gray "Vaginatenkalk", a reference that is seemingly erroneous when the other species referred by him to this same horizon are considered. Schindewolf (1942, p. 349) states that *Rhynchorthoceras* is confined to the B3b horizon (in Estonian terms) when, in fact, it has yet to be reported from that level by anyone other than Rüdiger. In Norway, *Rhynchorthoceras* ranges upward from the Ogygiocaris Series probably into the Lower Chasmops shale (4bα).

As others have noted, *Rhynchorthoceras* is strikingly similar to *Ancistroceras*, from which it differs, typically, in having no adapical coiled portion and in expanding much less rapidly orad. Furthermore, the configuration of the growth-bands and of the mature peristomes in these two genera are, for the most part, very similar. The rather simple, only sinuous growth-bands of early *Rhynchorthoceras* species (*e. g.*, *R. angelini*) mimic, throughout most of the length of the conch, those of mature *Ancistroceras*, whereas the more elaborate pattern developed by the presumably somewhat younger *R. helgoeyense*, n. sp., is more like the pattern developed in the early stages of *Ancistroceras*. As no noticeable ontogenetic changes in growth-band configuration are discernible in any of the described species of *Rhynchorthoceras*, one may be permitted to wonder if each of these species may not represent an uncoiled form derived independently from *Ancistroceras* at various stages in the evolution of that genus, rather than a separately evolving lineage only initially derived from *Ancistroceras*.

Rhynchorthoceras helgoeyense Sweet, n. sp.

Plate 4, figures 6, 9; Plate 14, figure 4; Plate 18, figures 2, 3; Plate 20, figure 3; text-figure 17.

Name: The specific designation refers to the island Helgøya, in Lake Mjøsa, on which the type locality is situated.

Type data: No complete specimen of this species is available, hence the following diagnosis and description are based on five specimens (P.M.O. 19, I 1538, 69297, 69298, 69299) all of which represent different (although in part overlapping) portions of the conch. All but one of these specimens (P.M.O. 19) came from the same horizon and locality and, as they clearly belong in the same species, they are considered to be syntypes, and to be of equal rank as types. I am well aware that it is desirable, when possible, to select as the "name-bearer" for a species, a single specimen, or holotype. None of the ones at hand, however, shows all of the significant features of the conch, and it would ill serve the purposes of taxonomy to tie the name and hence the specific concept of this new species to any single one of these species.

Material: Eleven incomplete specimens representing various parts of the conch. Several partially testiferous. Nine from the Cephalopod shale at Helgøya (Nes—Hamar district). One specimen, P.M.O. 19, from a drift block found between Nes and Ringsaker (Nes—Hamar district). One incomplete internal mold of the body chamber and the adoral two camerae of the phragmocone, probably from the Lower Chasmops shale (4bα) on Bygdøy, in the Oslo--Asker district.

Diagnosis: A slightly cyrtoceraconic longicone characterized by relatively long camerae and possessing prominently sinuous growth-lines which form dorsal, ventral, and lateral sinuses adapically, but only ventral and lateral sinuses adorally.

Description: The following description is a composite, based upon all five of the syntypes, no single one of which is described separately.

Conch a slightly curved longicone of essentially circular transverse section. A reconstruction, based on all 5 syntypes, indicates that the mature conch exceeded 500 mm in length, was curved only in the adapical one-fifth of its length, and expanded adorally rather regularly at the rate of 1 mm in each 5 to 7 mm. Adapically, there are three camerae in a length equivalent to the conch diameter; throughout the mid-portion of the phragmocone, only two camerae occupy this distance; and, the adoral 2 or 3 camerae seem to be somewhat more closely spaced so that, in that part of the phragmocone, about 3 occur in a distance equal to the lateral diameter of the conch. The body chamber is long, representing about a third the total length of the conch. The sutures are straight and directly transverse to the long axis of the conch; the septa are subhemispherical, and have an adapical concavity equivalent to slightly less than the length of half a camera.

The surface of the test, and to a lesser degree that of the internal mold, is marked by sinuous, transverse growth-bands which form, on the adapical part of the conch, rather prominent ventral and lateral sinuses and broad, shallow dorsal sinuses. Adorally, however, the dorsal sinus becomes progressively less prominent so that the mature peristome is marked by ventral and lateral emarginations and an essentially flat-crested dorsal salient.

The siphuncle is circular in section, one-eighth to one-tenth the diameter of the conch, and located slightly ventrad of the center at all stages observed. It is composed of long, straight septal necks (which extend apicad for about one-fourth the length of the camera) and laminated connecting rings, the structure of which is shown diagrammatically in text-figure 15B. It has not been possible to ascertain the detailed microstructure of either of the two layers which make up the connecting ring, but a strong similarity between these laminae and those of *Nautilus* (*see*, for example, Appelöff, 1893:

Stenzel, 1952, p. 15, fig. 13: Mutvei, 1956, p. 180, fig. 1) suggests that the thin, clear, somewhat irregular outer layer of *R. helgoeyense* corresponds in structure to the outer lamina of porous, spicular carbonate in *Nautilus*, and that the relatively thick, dark-colored inner layer is essentially like the inner "chitinous" layer of *Nautilus*. In *R. helgoeyense*, however, there is nothing to suggest that either the inner or outer laminae of the connecting rings grades into and becomes continuous with the septum, as appears to be the case in *Nautilus*.

Near, or slightly apicad of cameral mid-length, the connecting rings are discontinuous ventrally, or ventrolaterally, at least in those camerae which are occupied by cameral deposits. This perforation is not always in the same position with respect to the dorsum and venter, and its edges are irregular and uneven which suggests that it was formed by resorption of a part of the connecting ring after that structure had been completely secreted around the siphuncle.

Organic calcareous deposits, similar to those described in other lituitid genera, occupy the camerae of *Rhynchorthoceras helgoeyense* in at least the apical third of the conch. These structures consist of laminated epi-, and hyposeptal deposits which are continuous ventrally and laterally, but not dorsally, on which side a prominent hiatus, occupied by a subsequently secreted "vertical lamella" is present. The disposition of these deposits is illustrated diagrammatically in text-figure 17a—g, which shows a series of transverse sections made from a small but otherwise typical representative of this species. The structure and disposition of the deposits, together with their relation to the ectosiphuncle and the endosiphuncular deposits is shown in figure 3 on Plate 20. From these illustrations, and from a careful study of the several specimens available, it seems logical to conclude that, at some time subsequent to the formation of the connecting rings, a hole was resorbed on the ventral side of the rings permitting a "balloon-shaped" segment of the siphuncular tissues to expand into the camerae. From the outer surface of this inflated siphuncular tissue, thin layers of calcium-carbonate were secreted ventrally and laterally, but not dorsally, for it seems that, on that side of the camera, the opposite sides of the inflacted siphuncular tissue failed to meet in the early stages. Concurrent with the deposition of carbonate in the camerae, thin, somewhat irregular layers of the same composition were

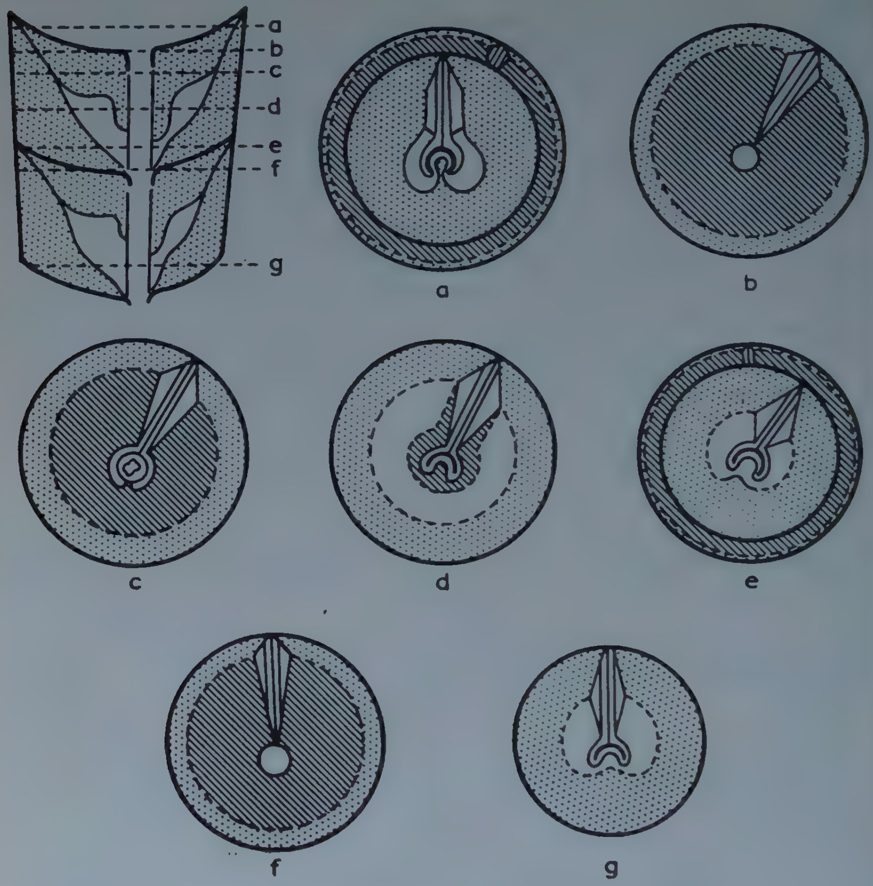

Fig. 17. *Rhynchorthoceras helgoeyense*, n. sp. Diagrammatic views (a—g) of transverse serial sections through two adapical camerae of a small specimen. Location of transverse sections indicated in the upper left-hand diagram, which represents a median lateral section through the same specimen. Episeptal deposits stippled; hyposeptal deposits cross-ruled; septa, conch wall, and connecting rings shown by heavy lines; broken lines represent junction between epi-, and hyposeptal deposits; laminae in "vertical lamella" shown by somewhat finer, solid lines. All of the transverse sections oriented with venter down.

laid down against the inside of the ectosiphuncle. The laminae of these deposits can, in many cases, be traced directly into those which form the cameral masses. After the camerae were partially filled by the encroaching epi-, and hyposeptal deposits, it seems probable that a pair of bulbs, representing the opposed ends of the now shrunken siphuncular "balloon" continued to exist in the dorsal hiatus and that, as the surfaces of these came in contact with each other, thin laminae of calcium-carbonate were secreted between them to form the so-called "vertical lamella".

Near the adapical end of the body chamber of a specimen from either the Lower Chasmops shale or Lower Chasmops limestone, there is an incomplete impression of a structure that appears to represent the attachment areas for the retractor musculature. A reconstruction of the annular elevation, based on this impression, is shown in text-figure 12B, and I can add little by way of description to the information conveyed by that illustration. No trace of "conchial zone II" can be found, and the incompleteness of the impression which probably represents "conchial zone I" makes it difficult to be certain that it is, indeed, a muscle "scar". However, it has the general configuration that might be expected in the lituitids, hence it is illustrated largely for the sake of completeness.

Remarks: In conch form, rate of expansion, and configuration of internal structures, *Rhynchorthoceras helgoeyense* is not greatly different from a number of the species of *Rhynchorthoceras* previously described. However, its camerae are relatively much longer than are those of other known species, and the sinuosity of the growth-bands is considerably more prominent than in any species heretofore described. The configuration and development of the ornamentation in this species is, as a matter of fact, more like that of the common species of *Ancistroceras* than it is like other species of *Rhynchorthoceras*. Among described representatives of *Rhynchorthoceras*, this new species most closely resembles *R. zaddachi* Remelé, but it differs from that species in having more prominently sinuous growth-bands which form a ventral sinus, a somewhat more rapidly expanding conch, and relatively longer camerae.

Distribution: Nine of the eleven available representatives of this species come from the Cephalopod shale at Hovindsholm, Helgøya

(Nes—Hamar district); one conspecific specimen comes from a drift-block between Nes and Ringsaker (Nes—Hamar or Ringsaker districts); and a single, distorted internal mold, which also appears to be conspecific was collected from a rubble heap on Bygdøy (Oslo—Asker district). Ostracods (*Ullerella holtedahli* (Dons)) associated with the latter indicate that it probably came from either the Lower Chasmops shale (4bα) or the Lower Chasmops limestone (4bβ).

Rhynchorthoceras angelini (Boll)?

?1857. *Lituites angelini* Boll, Archiv d. Verein des Freunde d. Naturgesch. in Mecklenburg, Jahrg. 11, p. 89, pl. 4, fig. 11.
?1882. *Rhynchorthoceras angelini* Remelé, Zeitschr. d. deutsch. geol. Ges., Bd. 34, p. 135.

Material: Two crushed, partially testiferous internal molds (P.M.O. 69300, 69301) probably from the Ogygiocaris beds of the Oslo—Asker district. Neither specimen merits illustration.

Description: The two specimens which I am tentatively referring to *Rhynchorthoceras angelini* (Boll) are similar in that they expand rather gradually, have simple transverse sutures, and have about 4 camerae in a length equivalent to the conch diameter. The growth-bands of the test, although disturbed by distortion, seem to have been only slightly sinuous, rather closely spaced, and oblique to the sutures. Apparently they formed very shallow, broad, asymmetrical lateral sinuses and virtually flat-crested dorsal and ventral salients. The siphuncle is central or slightly ventrad of the center in the most nearly complete specimen, but nothing can be determined of its structure.

Remarks: Rhynchorthoceras angelini may be distinguished from other species of that genus by its rather gradual rate of enlargement and by the markedly oblique, but only slightly sinuous course described by the growth-bands of its test. In that the specimens at hand exhibit all of these features, they resemble *R. angelini*. However, both of them are so poorly preserved that positive identification or more detailed comparison is not possible.

Distribution: The two specimens came from the Ogygiocaris beds at Helsvær, Østre gravlund, Oslo (Oslo—Asker district).

GENUS *Lituites* Bertrand, 1763.

[= *Hortolus* of authors (*not* Montfort, 1808);
= *Spirulites* Parkinson, 1811].

Type species: Lituites lituus Montfort, 1808.

The name *Lituites* was widely used in the past for coiled nautiloids in which the outer volution became free or straight. As the genus is understood at present, however, it includes only those lituitids characterized by 5 lappets (ventrolateral and dorsolateral lappet pairs, and an unpaired dorsal lappet) in the late mature peristome, and a relatively slowly expanding (but rather long) conch marked externally by transverse growth-lines and annulations, the salients and sinuses of which correspond to the apertural lappets and emarginations. The whorls of the coiled part of the conch may be closely approximated (but not dorsally impressed), or loosely gyroceraconic, even within an otherwise homogeneous specific sample. As a rule, the shell cross-section increases in area rather rapidly in the coiled part, somewhat less rapidly in the straight portion of the phragmocone, and only slightly in the body chamber, which may equal or exceed the straight phragmocone in length. The siphuncle, like that of other lituitids, is orthochoanitic and tubular. In the initial camera of at least one species (*L. perfectus* Wahlenberg) the siphuncle is ventral in position, but moves toward the center in the next 3 or 4 camerae and, in the remainder of the phragmocone, is subdorsal in position. The camerae are occupied by cameral deposits which are apparently similar to those described in the familial diagnosis above.

Remarks: Klein (1731) was the first to describe and illustrate a representative of this genus, but the name *Lituites* was used for the first time and for forms similar to those Klein described, by Breyn in 1732. For this reason, Breyn is commonly cited as the author of the name *Lituites*. It should be pointed out, however, that Breyn limited the term *Lituites* to the steinkern, employing the name *Lituus* for the shell. As others have pointed out, though, Breyn can not be considered a Linnéan author, nor can the names he employed for fossils be regarded as having any status under the Rules of Nomenclature. Teichert (1940, p. 594) was of the opinion that Gmelin (1793) was probably the first Linnéan author to use and define the name *Lituites*. The name was used in 1763, however, by Bertrand (p. 89 and p. 284) whose restriction of it to "... ces tuyaux [of *Orthoceratites*] sont recourbes ..." together with his references to Klein's and Breyn's studies, seems to constitute an adequate, if rather broad and unsatisfactory definition of the genus. Furthermore, Bertrand's introductory remarks indicate that he was fully acquainted with the Linnéan system of binominal nomenclature, and his occasional use of it elsewhere in his two-volume dictionary indicates that he can probably be regarded as a Linnéan author. Thus, insofar as I can determine, the name *Lituites* should be ascribed to Bertrand (rather than to Breyn or Gmelin). No species are cited by Bertrand, and thus the name was available in 1763 for "... all of the species of the world which would come under the generic description as originally published ..." (Summary of Opinion 46, I.C.Z.N.) *Lituites lituus*, proposed in 1808 by Montfort, appears to be the first such species named, and it has long been regarded as the type of the genus.

At present, undoubted representatives of *Lituites* are known only from the early Middle Ordovician of the Scando-Baltic province. The oldest species known to me are from the lower Platyurus limestone of Sweden, whereas the latest certain species are found in strata comparable in age to the Ampyx limestone of the Oslo Region. It should be stated, however, that small, generically indeterminate lituitids from the Upper Chasmops limestone and from the lower part of the Tretaspis Series of the Oslo Region may be referable to *Lituites*, as may some of the undescribed specimens from the Boda limestone of Dalarna, Sweden. None of these forms can be referred to the genus (or to any other) at the present time.

Lituites lituus Montfort?

Plate 14, figure 5; Plate 15, figure 4.

?1808. *Lituites lituus* MONTFORT, Conchyliologie systematique, vol. 1, p. 278—280.

Material: Three fragmentary internal molds, one partially testiferous, from the Ogygiocaris Series, and one distorted internal mold from the Ampyx limestone (basal Chasmops Series).

Descriptions: The specimen illustrated in figure 5 on Plate 14, (P.M.O. I 0264), is a fragment 57 mm long, which represents the left side of a body chamber to which recrystallized patches of the shell adhere. The convexity of the specimen indicates that it was essentially circular in cross-section, and it has a dorso-ventral diameter of 49 mm at the adoral end. The preserved portion of the shell, which is about 1 mm thick, is crossed by six conspicuous, broadly rounded annulations, the crests of which are about 10 mm apart and rise about 4 mm above the intervening troughs. Between the crests of adjacent annulations, there are from 13 to 15 growth-lines. The annulations and growth-lines form deep ventral sinuses (which are incompletely preserved), ventrolateral salients which rise about 11 mm above the lowest part of the ventral sinuses, broad, shallow lateral sinuses with troughs about 5 mm below the ventrolateral salients, broad dorsolateral salients and sinuses, and a low dorsal lobe which is also incomplete.

The specimen shown in figure 4 on Plate 15, (P.M.O. I 1732), is a compressed internal mold, 84 mm long, of part of a body chamber which attained a maximum diameter of about 50 mm. This specimen is similar in other comparable features to the one described in the preceding paragraph, but it is less well preserved.

A third specimen from the Ogygiocaris Series (P.M.O. 56557) also provisionally included in *L. lituus* Montfort, is a steinkern, 52 mm long and 50 mm in diameter at the adoral end. This specimen has been obliquely distorted but it is similar in general aspect to the two previously described.

A specimen from the Ampyx limestone (P.M.O. I 0266) probably belongs in *L. lituus*, but it is too poorly preserved to merit either illustration or detailed description. It is a partly testiferous fragment of a large body chamber, the annulations of which exhibit ventrolateral and dorsolateral salients, and ventral and lateral sinuses. The dorsum is not preserved. This specimen is similar to the three slightly older forms described above, but, like them, it can not be placed in any species of *Lituites* with complete certainty.

Remarks: The four fragments at hand agree rather well in details of surface sculpture with more nearly complete representatives of *L. lituus*, such as the one described by Holm in 1891. All of these forms are, however, somewhat larger than appears to be normal.

Distribution: Three specimens come from the upper part of the Ogygiocaris Series (probably from the Ogygiocaris shale). They were collected at Engervik, Asker, and Hjortnestangen, and Vigelands Fontene, Oslo (all in the Oslo—Asker district). A single specimen, which appears to be conspecific, was collected by Prof. Olaf Holtedahl from the Ampyx limestone (4aβ) at Gullerud, Norderhov, in the Hadeland district.

Lituites perfectus Wahlenberg.

Plate 14, figures 2, 3; ?Plate 16, figures 2, 4.

Lituites perfectus WAHLENBERG, 1818, Petrificata Telluris Suecanae, p. 83; — — — WAHLENBERG, 1821, Petrificata Telluris Suecanae, p. 83; — — — BRONN & ROEMER, 1850, Lethaea geognostica, 3d ed., v. 1, p. 494, pl. 1, fig. 3a; — — — BOLL, 1857, Archiv d. Verein des Freunde d. Naturgesch. in Mecklenburg, Jahrg. 11, p. 85, pl. 9, fig. 31a—e; — — — LOSSEN, 1860, Zeitschr. d. deutsch. geol. Ges., Bd. 12, p. 19; — — — REMELÉ, 1880, Festschr. f. die 50 jährige Jubelfier der Forstakad., Eberswalde, pl. 1, fig. 2a—b [*not* pl. 1, fig. 3]; — — — REMELÉ, 1890, Diluvialgesch. d. Norddeutsch. Flachlandes, I Stuck, 3. Lief., pl. 1, fig. 2a—b; pl. 6, fig. 3a—c; — — — HOLM, 1891, Geol. Fören. i Stockholm, Förh., bd. 13, no. 7, p. 12—20, pl. 2, fig. 1—5; — — — [pars] PATRUNKEY, 1926, Zeitschr. f. Geschiebeforsch., Bd. 2, p. 118—119; — — — BALASCHOV, 1953, Trudy V.N.E.G.R.I., n. ser., no. 78, p. 334—35, pl. 14, fig. 4.

Lituites striatus BOLL, 1857, Archiv d. Verein des Freunde der Naturgesch. in Mecklenburg, Jahrg. 11, p. 86, pl. 9, fig. 31f.

Lituites tenuicaulis REMELÉ, 1890, Diluvialgesch. d. Norddeutsch. Flachlandes, I. Stuck, 3. Lief., pl. 3, fig. 2a—b;— — — PATRUNKEY, 1926, Zeitschr. f. Geschiebeforsch., Bd. 2, p. 118—19; ? — — — BALASCHOV, 1953, Trudy V.N.E.G.R.I., n. ser., no. 78, p. 231—32, pl. 14, fig. 1.

Material: One fragmentary internal mold preserving the peristome, and two additional specimens, of somewhat questionable affinities, representing fragmentary apical spirals. Other specimens in the collections at hand may represent *L. perfectus*, but, for various reasons, they can not be identified specifically.

Descriptions: The representative of *L. perfectus* depicted in figures 2 and 3 on Plate 14, (P.M.O. I 1736), is a partly testiferous steinkern, 80 mm long, representing part of a body chamber, at the adoral end of which portions of the modified peristome are preserved. The cross-section of the conch is essentially circular, with diameters of 40 mm at the aperture and 35 mm, 50 mm apicad of the lowest point of the ventral sinus. This indicates a growth-coefficient of 1:10, at least in the apertural region. The configuration of the growth-lines and annulations indicates that the aperture was modified by five lappets, separated ventrally, laterally, and dorsolaterally by relatively deep, rounded emarginations. The ventrolateral lappets are almost completely preserved, as is the outline of the hyponomic sinus which lies between them ventrally. These lappets project adorally 24 mm above the corresponding part of the lateral sinuses. In their free portions, they are symmetrically lanceolate in form and curve gracefully inward and dorsad, their pointed distal extremities reaching nearly to the lateral mid-plane of the conch. At their tips, the lappets are separated, from each other by a distance of approximately 10 mm. Each lappet is deeply furrowed longitudinally, with the ventral edge rising some 3 mm above the lateral edge. No shell is preserved in the lappets.

The hyponomic sinus is symmetrically U-shaped, and is the deepest of the apertural emarginations, its margin lying some 10 mm apicad of the deepest portions of the lateral sinuess. On the steinkern, the lip of this sinus projects ventrad, indicating that the shell was markedly thickened at the margin. The lateral sinuses are also broadly rounded, U-shaped emarginations, but the plane containing their axes is inclined adapically toward the venter, forming an angle of about 20° with the lateral mid-plane of the conch.

Neither the dorsolateral nor mid-dorsal lappets are preserved, but the presence of salients in the growth-lines and annulations near the aperture in the dorsolateral and dorsal zones suggests their former presence. These growth-lines, and the annulations which are parallel to them on the steinkern, form deep, broadly rounded ventral sinuses ventrolateral salients, shallow lateral sinuses, relatively low dorsolateral salients and sinuses, and a broad dorsal salient. The annulations represent periodic thickening of the shell parallel to the peristome, formed presumably at times when growth was temporarily halted. The apertural lappets were almost certainly not formed until growth was completed and the animal had reached its normal maximum size, for the lappets clearly restrict the opening of the aperture transversely.

In addition to the specimen just described, the collections at hand contain steinkerns of three detached adapical spirals (P.M.O. I 024, 69302, I 1539) which probably belong in *L. perfectus*, but can not be placed there with certainty for this part of the conch is known to vary between such wide limits that precise specific determination is difficult. All three specimens are similar; the most nearly complete (P.M.O. I 024) is illustrated as figure 4 on Plate 16, and a more fragmentary specimen (P.M.O. 69302) is shown in figure 2 on Plate 16. These specimens indicate that the spiral is widely gyroceraconic, consisting of about 2¼ open whorls which have an over-all diameter (measured parallel with the long axis of the straight portion of the conch) of 34 mm. All three specimens are broadly elliptical in cross-section, with a proportion between the major and minor axes of about 3:2. The siphuncle is small and lies well dorsad of center in the outer volution. The surfaces of all three specimens are marked by a series of sinuous transverse annulations which form ventral, lateral, and dorsal sinuses, and ventrolateral and dorsolateral salients, and diminish in prominence adorally. Each annulation occurs near the mid-point of a camera, of which there are about 15 in the outer half-volution of the larger of the two illustrated specimens.

Remarks: The aperturally complete specimen described above agrees in all comparable respects with the one from the Schroeteri limestone of Öland studied by Holm. It is also strikingly similar to the body chamber herein made the type of *Triliacnoceras norvegicum*, n. sp., but differs from that specimen in being essentially circular (rather than compressed) in section, somewhat smaller in size, and more rapidly expanding orad. In addition, there is a suggestion in the dorsolateral zones of a salient in the annulations, hence there was probably a pair of dorsolateral lappets. These structures are not found as primary features in *T. norvegicum*, and there are no dorsolateral salients in the growth-lines or annulations of that species. The adapical parts to which reference is made are somewhat greater in over-all diameter than the average of forms in collections available to Holm, but, in other respects, they agree rather closely with his descriptions. These forms can not be referred to *L. perfectus* with certainty, however, for the apical part of the conch in *Lituites* is known to vary between rather wide morphological extremes, even in a single species.

Distribution: Ogygiocaris Series (probably Ogygiocaris shale) at Akers Kirke (Oslo—Asker district), Hamar, in the Nes—Hamar district, and Konnerud, Land. (The latter locality is outside the Oslo Region, in the mountains west of the Toten district.)

GENUS *Trilacinoceras* Sweet, n. gen.

Name: The generic name refers to the three lappets of the adult peristome.

Type species: Lituites discors Holm, 1891.

Diagnosis: Conch lituiticonic with two to three open or approximated (but not impressed), compressed, planispiral whorls adapically, and adorally an essentially straight, slightly compressed orthoceraconic segment, of which nearly half the length is body chamber. Conch expands rather gradually hence appears to be essentially tubular adorally. Growth-lines and annulations prominent, forming conspicuously deep ventral sinus and five salients adapically, but only three salients (ventrolateral and dorsal) throughout most of uncoiled part. Peristome with incurving, tongue-shaped ventrolateral lappets, deep ventral sinus, and broad, low dorsal lappet. A secondary dorsolateral lappet pair may be formed in species which are probably transitional between *Lituites törnquisti* Holm and *Trilacinoceras discors* (Holm), but the development of these is not heralded in either the growth-lines or annulations at the extreme adoral end of the body chamber. Siphuncle dorsad of center throughout length of phragmocone.

Remarks: As Holm recognized when he described *Lituites discors*, this species differs from typical *Lituites* (*L. lituus*, *L. perfectus*) in several ways. That is, it is considerably smaller in over-all dimensions, expands less rapidly, is somewhat compressed at maturity, and produces a mature peristome with three (instead of five) lappets. These differences seem to me to be of more than specific value, hence, *L. discors* is here made the type of a new genus, for which the name *Trilacinoceras* is proposed. The genus appears to be most closely related to *Lituites*, and particularly to *L. törnquisti* Holm. The latter species also exhibits only three growth-line salients through most of its length, but, at maturity, it develops five, rather than only three, apertural lappets.

In this connection, it should be noted that *T. norvegicum*, n. sp., forms two small secondary lappets in the dorsolateral part of the peristome at a very late stage in the development of the apertural margin. This suggests that it is transitional between *L. törnquisti* and *T. discors*, and further that the development of a single dorsal salient (in place of the apparently more primitive dorsal salient and dorsolateral sinuses) is done in the early, rather than the late, ontogenetic stages. That is, in the sequence *L. törnquisti-T. norvegicum-T. discors*, new or more specialized characters seem to appear proterogenetically, with reversion to the more primitive condition adaperturally in *L. törnquisti*, and perhaps vestigially in *T. norvegicum*. In *T. discors*, however, the more advanced tri-salient configuration of the growth-lines appears well established, even in the mature peristome.

Holm reports *L. discors* from the uppermost red Lituites limestone (Platyurus limestone) at two localities, Öland and Dalarna. He also suggests that the species is represented by an incomplete body chamber from a drift boulder of light gray Lituites (= Schroeteri?) limestone, which Remelé (1880, p. 223, pl. 1, fig. 3) first described as *L. perfectus* but later (1890, pl. 1, fig. 3) referred with question to *L. fallax*. The species is abundantly represented in the collections I am studying from the Cephalopod shale in the Hadeland, Toten, and Nes—Hamar districts. It also occurs in the upper part of the Ogygiocaris shale in the Oslo district, and a new species, *T. norvegicum*, is described from the Ogygiocaris shale of the Nes—Hamar district. Specifically indeterminate forms are also found in the Ampyx limestone (4aβ) of the Oslo—Asker district.

Trilacinoceras discors (Holm).

Plate 13, figures 1, 4, 6; Plate 15, figure 5:
Plate 16, figures 1, 3, 7, 8, 10.

1880. *Lituites perfectus* REMELÉ, Festschr. f. die 50 jährige Jubelfier der Forstakad., Eberswalde, p. 223, pl. 1, fig. 3.

?1890. *Lituites fallax* REMELÉ, Diluvialgesch. d. Norddeutsch. Flachlandes, I. Stück, 3. Lief., p. 44, pl. 1, fig. 3.

1891. *Lituites discors* HOLM, Geol. Fören. i Stockholm, Förh., bd. 13, no. 7, p. 26—29, pl. 1. fig. 5—7; pl. 3, fig. 3—4.

1894. *Ancistroceras discors* HYATT, Am. Philos. Soc., Proc., v. 32, p. 508.

Material: In collections from the Ogygiocaris Series, there are 13 specimens, (P.M.O. I 0249, I 1497, I 1498, I 1499, I 1500, I 1650, I 1651, I 1658, I 1660, 31194), all fragmentary, which correspond closely in size, shape, and ornamentation to the ones upon which Holm based *T. discors*. In addition to these, there are 24 specimens (P.M.O. I 023, I 0143, I 0149, I 0152, I 0154, I 0156—0160, I 0164, I 0189—0192, I 0237, I 0238, I 0241, I 0248, I 1440, I 1515, I 1516, I 1563, 69303), mostly distorted, which represent the adapical portion of the conch. These can be associated rather certainly with the more distinctive adoral fragments, for there is preserved with two of them a significant length of the uncoiled phragmocone, and these segments clearly belong in *T. discors*.

Descriptions: All of the forms here referred to *T. discors* have conchs which are slightly compressed laterally throughout their length, expand slowly (about 1:15—1:20) and are marked externally by a series of growth-lines and annulations which form ventral and lateral sinuses and ventrolateral and dorsal salients. In two of these specimens, the mature peristome is essentially complete, and, as shown in figures 1, 4, and 6 on Plate 13, it is almost precisely the same in configuration and dimensions as the one Holm illustrates. The adapical fragments referred without question to this species show considerable variation in coil approximation, but the over-all diameter of the coiled portion seems to remain rather consistently between 23 and 30 mm. Several of them are attached to straight segments showing the growth-line configuration of *T. discors*, and one of them (figure 5 on Plate 15) has attached to it a straight segment, some 134 mm long, which is indistinguishable in its adoral part from the adapical portions of the specimens showing the mature peristome.

Remarks: The only species with which incomplete representatives of *Trilacinoceras discors* might be easily confused is *Lituites törnquisti* Holm. However, since all of the specimens referred to above come from a stratigraphic interval of younger age than the one which yields *L. törnquisti* (the Platyurus limestone of Sweden) and the adoral fragments clearly belong in *T. discors*, I do not hestitate to conclude that all of these specimens belong in the same species. They may be distinguished from *T. norvegicum*, n. sp., which is of about the same age, by their more slender, less rapidly expanding, and considerably smaller conchs.

Distribution: Trilacinoceras discors is widespread in the Oslo Region. Representatives of it are known from the Ogygiocaris shale (4aα_3) at Vulkans verkstedstomt, Oslo; Huk and Vekkopp, Bygdøy (all in the Oslo—Asker district), from the Cephalopod shale at Hovindsholm, Helgøya (in the Nes—Hamar district) and from the Ogygiocaris shale or Cephalopod shale at Lunder farm, Hadeland district. It is probable that this apparently ubiquitous species is the one which has been listed in older reports as "*Lituites lituus*".

Trilacinoceras norvegicum Sweet, n. sp.

Plate 15, figures 1, 3, and 7.

Name: The specific name, *norvegicum*, refers to Norway.

Type data: The holotype, P.M.O. I 1578, is an incomplete internal mold which preserves an essentially complete mature peristome. The label which accompanies it indicates that it was collected from an exposure at Storhamar, near the town of Hamar in the Nes—Hamar district. Although the label gives the "Ampyx limestone" as the stratigraphic horizon, this is doubtful, for the Ampyx limestone, as such, is not developed in the Nes—Hamar district, and the so-called Robergia beds, which represent about the same horizon in that area are rather sparingly fossiliferous. Furthermore, I have collected an essentially identical specimen from the upper part of the Ogygiocaris shale on Helgøya (almost directly across Lake Mjøsa from Storhamar), hence it seems likely that both come from the older Ogygiocaris shale.

Material: Two specimens of essentially similar size and representing about the same part of the conch. The best of the two is designated the holotype. The other (P.M.O. 69304) is somewhat distorted, and only one side is complete.

Diagnosis: A large species of *Trilacinoceras* which is laterally compressed at maturity and characterized by 3 primary apertural lappets (a ventrolateral pair and an unpaired mid-dorsal lappet) and a pair of low, secondary dorsolateral lappets, formed very late in the development of the mature peristome as low salients in the dorsal part of the lateral emarginations. Unlike the primary lappets, the position of the secondary dorsolateral pair is not marked by salients in the growth-lines or annulations. *T. norvegicum* differs from *T. discors* (Holm), the type of *Trilacinoceras*, in that it is considerably larger at maturity, the apertural lappets are longer and more pronounced, and a pair of secondary dorsolateral lappets are present in the mature peristome.

Description: The holotype is an internal mold, 60 mm long, which represents the adapertural portion of a body chamber and preserves, at its adoral end, an essentially complete mature peristome. The conch expands only slightly in that part of it preserved, is compressed in cross-section, and has lateral and dorso-ventral diameters of 39 mm and 44 mm respectively. The surface of the mold is marked by sinuous growth-lines and annulations which form deep, V-shaped ventral sinuses, sharp ventrolateral and broad dorsal salients, and shallow, asymmetrical lateral sinuses. The late mature peristome is marked by a deep, U-shaped ventral sinus; prominent incurved ventrolateral lappets which curve dorsad near their distal ends; broad, shallow, lateral sinuses, and a bluntly rounded mid-dorsal lappet, the margins of which are gently, but markedly incurved. The dorsolateral part of the lateral sinus is sinuous, being broken near its mid-length by a low, blunt, smoothly rounded salient which appears to have developed late in the formation of the peristome, for its position is not heralded by salients in the growth-lines or annulations, and the youngest of these pass directly across it with no noticeable deflection.

Immediately apicad of the peristome on the internal mold there is a trough-like constriction ventrally and laterally (but not dorsally). Apparently this represents a narrow zone of thick shell secreted laterally and ventrally to protect the delicately sculptured edge of the aperture. The secondary dorsolateral lappets occur at the dorsal extremities of this marginal constriction, and they may represent a zone transitional between the reinforced margin and the incurved, but apparently not thickened dorsal margin of the aperture.

Remarks: Although nothing is known of the early portions of the conch, this species clearly belongs in *Trilacinoceras*. It may be distinguished from *T. discors* (Holm) by its greater size, more pronounced lateral compression, and by the presence of low, secondary lappets in the dorsolateral part of the peristome. As pointed out previously, this species may be transitional between *Lituites törnquisti* (Holm, and

T. discors (Holm), and the secondary dorsolateral lappets may be vestiges of the original, and apparently more primitive 5-lappeted peristome.

Distribution: As pointed out under the heading "Type data", just above, there is some question as to the stratigraphic horizon which yielded the holotype. However, as has also been noted, a second, closely similar specimen was collected from rocks which without doubt belong in the upper part of the Ogygiocaris shale, hence it seems reasonable to conclude that both specimens came from the same horizon. Both are, in addition, from the Nes—Hamar district.

Trilacinoceras sp.

Plate 17, figure 5.

Material: Two specimens (P.M.O. I 0646, I 0647) both fragmentary, and both from the same horizon and locality, the Ampyx limestone as exposed in the immediate vicinity of the Royal palace in Oslo.

Description: Both specimens are somewhat distorted, but compression has least altered the shape of the one illustrated as figure 5 on Plate 17. This specimen, which is 113 mm long, appears to represent only a body chamber which was apparently essentially circular in cross-section, and expands from an adapical diameter of 27 mm to 33 mm, 60 mm orad of the adapical end. This indicates a growth-coefficient of about 1:10. Growth-lines and annulations form deep, rounded ventral sinuses, low ventrolateral salinets, asymmetrical lateral sinuses, and a broadly arched salient in the dorsolateral and dorsal zones. The crest of this salient extends about 4 mm farther orad than do those of the ventrolateral salient pair.

The unillustrated specimen agrees with the first in the configuration of the growth-lines and annulations, but it is somewhat larger. It is a badly distorted internal mold, 121 mm long, which represents the adoral 2 camerae of the phragmocone and the adapical 105 mm of the body chamber. It expands at the rate of 1:6, but this figure probably has little significance because distortion is not equal in all of its parts.

Remarks: These specimens quite probably represent an undescribed species of *Trilacinoceras* which differs from *T. discors* and *T. nor-*

vegicum in shape and size, and in the fact that the dorsal salients of the growth-lines are projected much more prominently orad. They also appear to be the youngest known representatives of the genus.

Distribution: Both specimens were collected from exposures of Middle Ordovician strata made during excavations for the Royal Palace, in Oslo. Although the specific stratigraphic horizon from which they were collected is not given on the labels which accompany them, the illustrated specimen bears the pygidium of an asaphid trilobite near its adoral end, and the fragmentary cranidium of a trinucleid adapically. Both of these trilobites probably belong in undescribed species, but, taken together, they indicate that the cephalopod probably came from some part of the Ampyx limestone (4aβ).

GENUS *Cyclolituites* Remelé, 1886.

Type species: Lituites applanatus Remelé, 1880.

Lituitids with discoidal, subdiscoidal, or subglobular, coiled conchs, of which the outer volution, the body chamber, or only its apertural end is not in contact with preceding volutions. Peristome of mature individuals with five lappets corresponding in position to growth-line salients. Siphuncle small, tubular, located well dorsad of center even at maturity.

Remarks: Cyclolituites is a distinct, if small genus, to which only four species can now be referred with certainty. Hyatt's (1894, p. 505—506) *C.? americanus*, from the St. George beds at Gargamelle Cove, Newfoundland, is excluded from *Cyclolituites*, for it is reported to have a conch 2 to 2½ times as large as any known from the Scandinavian Ordovician. Furthermore, the siphuncle of *C.? americanus* is "ventro-centran" in position (rather than subdorsal) and the cross-section (*see* Ulrich, *et al.*, 1942, p. 68, fig. 17H) of the conch is quite unlike that of any species of *Cyclolituites* known to me. The genus is closely related to *Lituites*, of which many authors (Schröder, 1890, p. 46; Ulrich, *et al.*, 1942, p. 75; Flower, 1955c, p. 251) believe it to be a juvenile form. It differs from *Lituites*, however, in that it remained small throughout life and developed no orthoceraconic free segment. The elaborate development of apertural modifications indicates, however, that known species of *Cyclolituites* are not juveniles of other lituitid genera, but fully grown individuals which never attained great size.

The only known specimen of the type species, *C. applanatus* (Remelé), was found in a drift boulder of light gray "Orthoceras limestone" near Eberswalde, Germany, from which erratic Remelé (1880, p. 241) also lists *Lituites perfectus*, *Asaphus raniceps*, *A. undulatus*, *Illaenus* cf. *schmidti*, and *Lichas* sp. The color of the rock and the presence of *Lituites perfectus* in it suggest the Schroeteri limestone of Sweden, but the trilobite assemblage, if correctly identified, seems more like that of the Vaginatum limestone. The only representatives of *Cyclolituites* which have been collected from strata in place, however, come from the Schroeteri limestone on Öland, and from the Cephalopod shale (or an essentially equivalent horizon) in the Hadeland and Nes—Hamar districts of the Oslo Region, Norway. All of these stratigraphic units are probably of nearly the same age, which suggests that *Cyclolituites* was a short-lived form which appeared only briefly in the Llandeilan.

Cyclolituites lynnensis (Kjerulf).

Plate 1, figure 2; Plate 8, figures 1, 2; text-figure 18A—D.

1865. *Lituites lynnensis* [pars] Kjerulf, Veiviser ved geologiske excursioner i Christiania omegn, p. 9, 14, fig. 22a [not fig. 22b].

1867. *Discoceras lynnense* Barrande, Syst. Sil. du Centre de la Bohême, pt. II, p. 177.

1894. *Cyclolituites lynnensis* Hyatt, 1894, Am. Philos. Soc., Proc., v. 32, p. 505.

Type data: In those parts of Kjerulf's collections from Lynne [now Lunder], Hadeland, which I have been able to locate, there are no specimens which correspond to both his drawings of *Lituites lynnensis;* there are, instead, representatives of two species of *Cyclolituites*, on a combination of which Kjerulf seems to have based his concept of *L. lynnensis*. Five specimens (R.M. MO 150023, MO 150022, MO 150026, MO 150031 (2 specimens)) which correspond closely to Kjerulf's figure 22a are, therefore, retained in *Cyclolituites lynnensis*, and the largest and most nearly complete of these (R.M. MO 150023) is designated as lectotype.

Material: In addition to the five specimens from Hadeland, six virtually identical specimens from the Cephalopod shale in the Nes—Hamar district (P.M.O. I 1575, I 1832 (4 specimens), I 1557) are also being referred to *C. lynnensis* (Kjerulf), and my understanding of the species is, therefore, based on all eleven specimens.

Descriptions: Cyclolituites lynnensis (Kjerulf) has a subdiscoidal conch composed of 2—2½ whorls which are strongly compressed laterally, slightly impressed dorsally, and prominently keeled ventrally near the aperture. The umbilical perforation is large; the outer volution of the conch is free only at its extreme adoral end. The late mature peristome is modified by five lappets which correspond in position to the dorsal, dorsolateral, and ventrolateral salients of the growth-lines and annulations. Siphuncle small in size, subdorsal in position in at least the outer whorl.

The lectotype, shown here in figure 2 on Plate 1, represents only the left side of a nearly complete individual. It is about 29 mm in diameter and consists of 2¼ volutions of a conch which is tightly coiled and whose volutions are strongly compressed laterally. The body chamber is 37 mm long and occupies the outer half volution. It expands from an estimated lateral diameter of 6 mm at its adapical end to about 12 mm at the adapertural end, indicating a growth-coefficient of about 1:6. The aperture is not complete, but the annulations immediately adjacent to the apertural end of the body chamber form prominent ventrolateral salients, broad lateral sinuses, low dorsolateral salients, and shallow dorsolateral sinuses. Their course on the venter and dorsum can not be seen. The umbilicus is open; the diameter of the perforation is about 2 mm.

The peristome is essentially complete on a specimen from the Cephalopod shale at Helgøya. This specimen, depicted in figure 2 on Plate 8, consists of a body chamber only, 24 mm long, which expands at the rate of 1:4, but is similar in other proportions to the lectotype. The apertural margin of this specimen is portrayed diagrammatically in text-figure 18A. From this figure it can be seen that the peristome is produced ventrolaterally and dorsolaterally into a pair of lanceolate lappets, separated ventrally and laterally by deep, U-shaped emarginations. Smaller emarginations occur on the umbilical shoulders, and a narrow, short, linguiform lappet occupies the dorsal segment of the

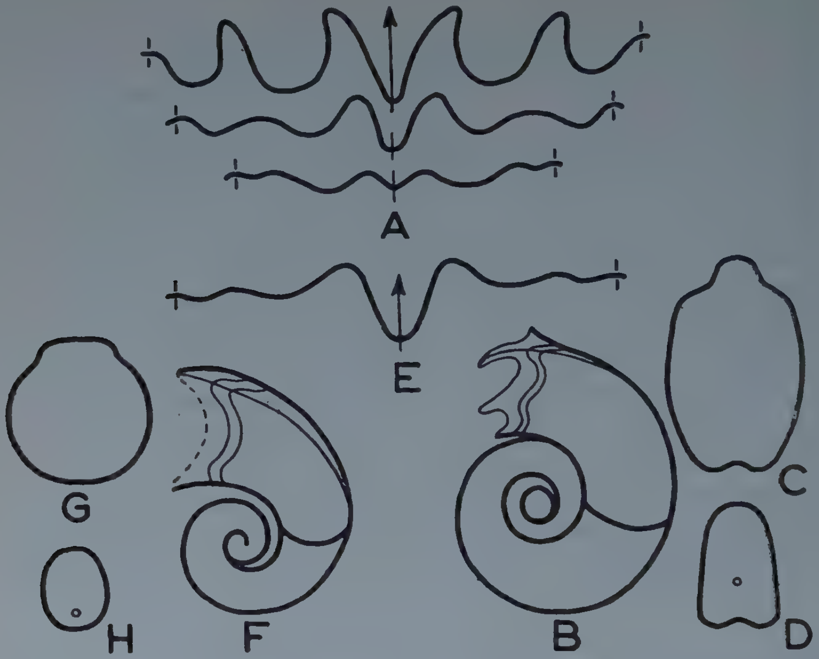

Fig. 18. (A—D) *Cyclolituites lynnensis* (Kjerulf). (E—H) *Cyclolituites kjerulfi*, n. sp. (A) and (E) are schematic representations of the adoral growth-line sequences, x2; (B) and (F) are diagrammatic lateral views, x1.5; (C) and (G) are cross-sections at the adoral end of the body chamber, x2; (D) and (H) are conch cross-sections at the adapical end of the body chamber, x2. Views of both species based on their respective holotypes.

margin. The venter is flattened throughout its length and near the adoral end it becomes distinctly keeled, bounded ventrolaterally by relatively deep furrows which continue adorally along the mid-portion of the ventrolateral lappets. Dorsally there is a conspicuous impressed zone, which terminates adorally 2 mm apicad of the tip of the dorsal lappet. Its position is marked in this segment, however, by a broad furrow which subdivides the dorsal lappet longitudinally.

A third specimen (figure 1 on Plate 8), also from Helgøya, is an essentially complete conch with a diameter across the umbilicus of about 25 mm. The body chamber of this specimen is 32 mm long, expands at a rate of about 1:8, is markedly flattened ventrally and laterally, and is impressed dorsally. The phragmocone is about 2 volutions in length; the umbilical perforation measures about 3 mm across. The course of the growth-annulations on the body chamber indicates that the mature aperture was produced into 5 lappets, although these are not preserved.

The remaining 8 specimens are mostly imcomplete portions of body chambers or of tightly coiled, laterally flattened phragmocones which agree closely in general configuration and dimensions with the more nearly complete specimens just described. Several of these fragments occur in the same rock samples with the figured individuals, hence there can be little doubt but that they all represent the same species.

Remarks: Cyclolituites lynnensis (Kjerulf) differs from *C. applanatus* (Remelé) chiefly in that it is dorsally impressed, whereas Remelé's illustrations of the type species indicate that in it the whorls are in contact, but not impressed. The Norwegian species is closely similar to *C. lynceus* Holm from the Schroeteri limestone of Öland. Holm's species, however, is somewhat broader adorally than *C. lynnensis* and the ventral keel of the outer volution is prominent for at least the full length of the body chamber, rather than being developed only adorally as in *C. lynnensis*.

Distribution: Representatives of this species are known at present from the Cephalopod shale at Lunder farm, Hadeland, and at Hovindsholm, Helgøya, in the Nes—Hamar district.

Cyclolituites kjerulfi Sweet, n. sp.

Plate 16, figures 5, 6, 9; text-figure 18E—H

1865. *Lituites lynnensis* [pars] KJERULF, Veiviser ved geologiske excursioner i Christiania omegn, p. 9, 14, fig. 22b [not fig. 22a].

Name: The specific name is in honor of Professor Theodor Kjerulf, whose important geological investigations of a century ago laid the foundation upon which later stratigraphic knowledge in the Oslo Region has been built.

Type data. In Kjerulf's collections, there are seven specimens (R.M. MO 150021, MO 150024, MO 150025, MO 150027, MO 150029, MO

150032, MO 150033), all fragmentary, upon at least one of which he appears to have based his drawing of the ventral side of *Lituites lynnensis*. These specimens can not remain in that species, however, for they differ in several essential respects from its type, as pointed out above. Consequently, they are here referred to a new species, *Cyclolituites kjerulfi*, and the most nearly complete specimen (R.M. MO 150021) is designated the holotype.

Diagnosis: Conch subglobular, rapidly expanding, with only the innermost volution tightly coiled. Whorls slightly compressed laterally broadly rounded ventrally, with a broad, mid-ventral keel representing successive positions of a low, spout-like hyponomic process. Annulations (and, presumably, also growth-lines) form deep, U-shaped ventral sinuses, asymmetrical ventrolateral salients, broad, shallow lateral sinuses, and a low, broad dorsal salient. Mature peristome not known, but presumably it has five lappets corresponding in postition to the growth-line salients. Siphuncle persistently subdorsal in position.

Descriptions: The holotype, shown in figure 9 on Plate 16, is a steinkern with a maximum diameter (measured across the umbilicus) of 20 mm, which represents about $2^1/_8$ volutions of the conch. One and three-fourths volutions are phragmocone, whereas the outer three-eighths volution, which is 16 mm long, is body chamber. The inner volution is tightly coiled, but the dorsal side of the outer one is separated from the venter of the preceding whorl by about 0.5 mm at the end of half the outer volution, and by about 2 mm at the adoral end of the body chamber. The dorsoventral diameter of the conch at the adapical end of the body chamber is 6 mm; a comparable measurement at the adoral end of the specimen is 11 mm. This indicates a growth rate of about 1:3. The rate of expansion in the adoral half volution of the phragmocone, however, is only 1:6. Both the phragmocone and body chamber are somewhat compressed laterally so that, as shown in text-figure 18G—H, the cross-section is somewhat elliptical. In the adoral half of the body chamber, the venter becomes swollen along its mid-portion, forming a broad keel which corresponds in width and position to the ventral sinuses in the growth-lines. Annulations form a pattern of sinuses and salients like that given in the specific diagnosis.

The remaining six specimens, of which only two are illustrated, are similar in that, with one exception, they represent only internal molds of the body chamber. One specimen (unillustrated) differs slightly from the rest in that is outer volution appears to be in contact with the inner one nearly as far orad as the proximal end of the body chamber. No particular significance is attached to this, however, as the specimen is comparable in all other respects to the holotype and details of coiling seem to be of little taxonomic value in the lituitids.

Remarks: Cyclolituites kjerulfi differs from other known species of the genus in that, typically, it is uncoiled for a greater part of its length than are the others, and it is not markedly compressed laterally. It resembles the others, however, in over-all size, details of surface sculpture, and in the presence of a low ventral keel adorally.

Distribution: The seven known specimens of this new species all come from the Cephalopod shale at Lunder farm, in the Hadeland district.

?GENUS *Tyrioceras* Strand, 1933.

Tyrioceras? sp.

Plate 14, figure 1.

Material: One fragmentary, somewhat distorted specimen (P.M.O. I 1840) from the Lower Chasmops limestone (4bβ) on Nakholmen island (Oslo—Asker district).

Description: Specimen 100 mm long, representing an internal mold of at least one camera of the phragmocone, to which is attached a considerable length of the body chamber. The specimen is distorted, but the siphuncle appears to have been essentially central and the growth-bands form three sinuses (ventral, ventrolateral, and dorsolateral) and a dorsal salient. Except for distortion, the growth-band configuration is similar to that exhibited by *Tyrioceras kjerulfi* Strand. This similarity is strengthened by the fact that the bands themselves are broad and adapically imbricated, as is the case in the type series of *Tyrioceras*.

Remarks: The presence of an additional sinus in the growth-bands of this specimen distinguishes it from *Ancistroceras* and *Rhynchorthoceras* (which it resembles in other respects) and suggests a relationship with *Tyrioceras*. It is, however, so poorly preserved that I am not certain as to its generic affinities. A brief description and an illustration of this specimen are included, however, largely for the sake of completeness.

Distribution: The specimen described above is from the Lower Chasmops limestone (4bβ) on Nakholmen island in the Oslo—Asker district.

Suborder **Discosorina** Flower, 1940

[*nom. trans.* herein (*ex* Discosoroidea Flower, 1940;
Discosorida Flower, 1957)].

FAMILY Ruedemannoceratidae Flower, 1940.

?GENUS *Ruedemannoceras* Flower, 1940.

Ruedemannoceras? sp.

Plate 15, figure 6; Plate 17, figure 2.

Material: Three fragmentary specimens (P.M.O. I 2211, 69305, 69306) from the Cephalopod shale at Hovindsholm, Helgøya (Nes—Hamar district) may represent *Ruedemannoceras* Flower, or some closely allied generic group, but they are so incomplete that they can not be referred to that genus (or to any other) with certainty.

Descriptions: The specimen shown by figure 2 on Plate 17, is a hollow external mold of the left side of a cyrtoceraconic conch, in the adoral portion of which an internal mold of the body chamber is preserved. The cross-section, which can be seen at the adapical end of the body chamber, is essentially circular, although the dorsoventral diameter is about 1 mm less than the lateral one, which may indicate a slight depression of the conch. On the adapical two-thirds of the phragmocone, the dorsal and ventral margins describe regular curves which are circular arcs of fairly short radii; however, orad of this, the curvature of the conch decreases considerably. A slight inward curvature of the sides adorally suggests that the aperture may have been somewhat contracted. Near the apertural end of the body chamber, the internal mold exhibits a prominent constriction, which, however, does not occur in the adjacent external mold. This indicates that the shell was thickened internally apicad of the aperture, and suggests that the specimen represents a mature individual.

The surface of the test, as seen from its external mold, was marked by a series of closely spaced growth-lines which are directly transverse to the curving axis of the conch. The surface of the external mold is also crossed by a number of broad annulations which are parallel to the lines of growth.

The phragmocone has been entirely removed by weathering, but, at the adapical end of the body chamber, the position and size of the siphuncle are indicated by a subcentral, circular projection, 5 mm in diameter, the adapical margins of which flare slightly, suggesting that the septal necks were cyrtochoanitic.

The specimen shown in figure 6 on Plate 15 is an incomplete internal mold, 45 mm long, which represents a segment of a slightly curving body chamber. Both the venter and the dorsum of this specimen curve, and, near mid-length, it has dorso-ventral and lateral diameters of 28 and 29 mm, respectively, which indicates that the conch is slightly depressed. The surface of the mold is crossed by a series of rather prominent annulations, some 3 mm apart on the sides, which are essentially normal to the curving axis of the conch, but somewhat more widely spaced on the convex than on the concave side of the conch.

An unillustrated specimen, P.M.O. 69306, is similar to the two just described in curvature, size, and surficial markings, and it is almost certainly conspecific with them.

Remarks: Although none of the features exhibited by the three specimens mentioned above necessarily restrict them to either *Ruedemannoceras* or to the family to which it belongs, it should be pointed out that the large, subcentral, apparently cyrtochoanitic siphuncle and cyrtoceraconic conch would be unusual in any other known group of early Paleozoic nautiloids. The specimen at hand are somewhat more curved than are the three North American species of *Ruedemannoceras*, but in the other comparable respects they are quite similar to them.

Distribution: All three of the specimens herein tentatively referred to *Ruedemannoceras* were collected from the Cephalopod shale at Hovindsholm, Helgøya, in the Nes—Hamar district. Peculiarly, they represent the bulk of the cyrtoceraconic forms now known from that richly fossiliferous locality.

FAMILY Westonoceratidae Teichert, 1933.

GENUS *Broeggeroceras* Sweet, n. gen.

Name: This new genus is named in honor of the late Professor W. C. Brøgger, of Oslo University.

Type species: Broeggeroceras contractum Sweet, n. sp.

Diagnosis: Conch an exogastric, slightly depressed brevicone with markedly contracted aperture. Siphuncle ventral, cyrtochoanitic, with short, strongly recurved septal necks and thickened connecting rings which expand moderately within the camerae. Adapical ends of connecting rings not produced into bullettes. Camerae apparently empty.

Remarks At the present time, representatives of *Broeggeroceras* are known only from the Oslo Region, Norway. The type species occurs in the Lower Chasmops limestone (4bβ), and a second species, only tentatively referred to this genus, is found in Upper Ordovician strata which belong in the interval 4cβ—4cγ. Morphologically, *Broeggeroceras* seems to be most closely related to *Simardoceras* Flower, from which it differs, however, in having an elliptical (rather than a lachrimiform) cross-section, and apparently no organic deposits within the siphuncle.

Broeggeroceras and *Simardoceras* are reminiscent of *Winnipegoceras* Foerste, but the latter genus is typically more strongly curved, has a greatly produced body chamber, and is compressed in cross-section.

Broeggeroceras contractum Sweet, n. sp.

Plate 19, figures 1, 2, 3; Plate 21, figure 2;
text-figure 19A—C.

Name: The specific name refers to the adapertural contraction of the body chamber.

Type data: The single specimen upon which this species is based (P.M.O. I 0346—47) was collected by W. C. Brøgger, and is accompanied by a note, in the handwriting of August F. Foerste, stating that it is a "new genus of *Cyrtoceras*". There is little doubt but that this

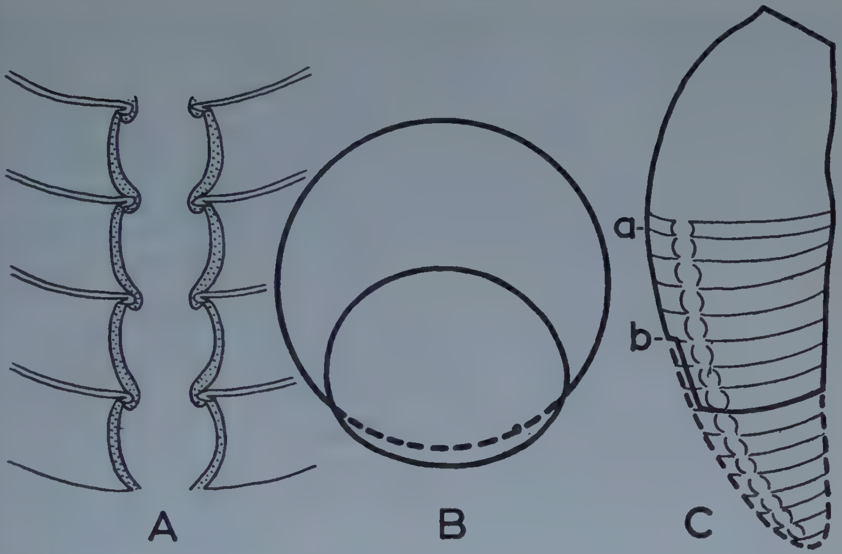

Fig. 19. *Broeggeroceras contractum*, n. gen. & sp. (A) Diagrammatic lateral section through the siphuncle between "a" and "b" in (C), x2. (B) Superimposed outlines of conch at adapical end of body chamber and apertural margin, x1. (C) Diagrammatic section of conch, x0.5, with suggested adapical restoration. All diagrams based on the holotype. (*See* also figure 2, Plate 21).

specimen does, indeed, represent a heretofore undescribed generic group, and it is here designated the holotype of *Broeggeroceras contractum*, n. gen. & sp.

Diagnosis and description: The holotype and only known representative of this new species is an incomplete internal mold, 96 mm long, which consists of the adoral 8 camerae of the phragmocone and an essentially complete body chamber. The conch is depressed, breviconic, and attains its greatest height and width (42 mm and 44 mm, respectively) at the adapical and of the body chamber. The venter is convex, with its point of maximum convexity located at the adapical end of the body chamber. There is an additional dorsal convexity in the adoral half of the body chamber. The sides are convex, except on the body chamber, where they become concave for short distances opposite the dorsal contractions. The mature peristome is complete dorsally and laterally. It is dorsally inclined, elliptical in shape, and has dorso-ventral and lateral diameters of 26 and 32 mm, respectively. The constriction which immediately precedes it adapically presumably represents a thickening of the mature shell margin.

The camerae are short (6.5 in a length equal to the maximum dorso-ventral diameter of the conch), and separated by shallow septa which join the conch walls to form essentially straight, transverse sutures. The adoral camera is only half the length of those preceding it adapically, which indicates that the specimen represents a mature individual. At the adapical end of the body chamber, there is a distinct "basal zone", consisting of a crenulated line approximately coincident with, but slightly orad of the adoral suture. The crests of this line coincide in position with a series of longitudinal grooves faintly preserved on the phragmocone and body chamber.

The position and structure of the siphuncle are shown diagrammatically in text-figure 19A and C. From these figures it can be seen that the siphuncle is large and subventral in position adorally, but proportionately closer to the margin adapically, suggesting that, in the missing early stages, it was probably submarginal. The septal necks are short and so strongly recurved as to be essentially recumbent. The connecting rings expand slightly within the camerae and are free adorally, but adnate to the surface of the septum for a short distance adapically. They are markedly thickened and attain their greatest width in the adapical part of the camerae. Their inner surfaces project farthest toward the center of the siphuncle at the septal foramen, but no noticeable annuli are formed there. Preservation of the specimen does not permit a more detailed study of the siphuncular structure.

No cameral deposits are discernible and it seems unlikely that any were originally present. It might be mentioned, however, that longitudinal grooves, similar to those which mark the exterior of the specimen at hand, are regarded by Flower (1946, p. 50; 1955d, p. 100) as an expression on the internal mold of incipient cameral deposits. However, the fact that these grooves are coextensive with the ones marking the surface of the body chamber suggests that they are not impressions of cameral deposits, but represent longitudinal "ribs" on the shell's inner surface which were probably primary structures formed in persistent folds or wrinkles in the pallial surface of the animal. The fact that these longitudinal markings extend well orad of the apical end of the body chamber also seems to exclude the idea that they are related, in any way, to the areas of muscle attachment on the inner surface of the conch.

Distribution: The specimen just described was collected by Professor Brøgger from the Lower Chasmops limestone (4bβ) on Nakholmen island in the Oslofjord (Oslo—Asker district).

Broeggeroceras? elongatum Sweet, n. sp.

Plate 18, figures 4, 5, 6.

Name: The specific name refers to the elongate conch of this species.

Type data: The holotype (P.M.O. 62088) and only known specimen of this new species is an incomplete internal mold which has been sectioned longitudinally. It was collected from Upper Ordovician strata belonging in either substage 4cβ or substage 4cγ, at Rauskjær, Vestfjorden, in the Oslo—Asker district.

Diagnosis and description: The holotype of this species is an internal mold, 112 mm long, which represents 7 (and parts of 8) camerae of the phragmocone and an essentially complete body chamber. In cross-section, the conch is depressed, having dorso-ventral and lateral diameters of 38 and 46 mm, respectively, at the adapical end of the body chamber. The venter is smoothly and evenly curved throughout its length, but the general concavity of the dorsal profile is broken by a slight convexity over the adapical two-thirds of the body chamber. The sides are convex, contracting both adapically and adorally. The mature peristome is almost completely preserved. Its margin is simple, its dorso-ventral and lateral diameters 33 and 38 mm, respectively, and it slopes apicad from venter to dorsum.

The camerae are short, about 8 occurring in a length equivalent to the dorso-ventral diameter of the conch. The adoral camera is somewhat shorter than those preceding it adapically, hence it is probable that the specimen represents a mature individual. The septa are shallow, and the sutures slightly sinuous, forming broad, shallow dorsal and ventral lobes, and low lateral saddles. The surface of the internal mold is marked, also, by a series of fasciculate longitudinal ribs or ridges which are most prominent on the surface of the phragmocone, but continue into at least the adapical third of the body chamber. None of the internal structures of the conch are preserved, but a circular structure about halfway between the center and the venter at the adapical end of the specimen indicates the position and size of the siphuncle. This structure is 4 mm in diameter, and its center is located some 8 or 9 mm from the ventral margin of the conch.

Remarks: Lack of detailed information concerning the structure of the siphuncle in this species makes it impossible to assign it with certainty to *Broeggeroceras*, which it strongly resembles in other respects. As in *Broeggeroceras contractum*, however, the considerable depression of the conch serves to distinguish this new species from other westonoceratids, to which group it almost certainly belongs.

Distribution: The holotype is from either the Tretaspis limestone (4cβ) or the Upper Tretaspis shale (4cγ) at Rauskjær, Vestfjorden, in the Oslo—Asker district.

FAMILY Cyrtogomphoceratidae Flower, 1940.

GENUS *Strandoceras* Flower, 1946.

Type species: Protophragmoceras tyriense Strand, 1933.

Compressed, endogastric cyrtoceracones of rather marked curvature, which are lachrymiform in transverse section, the venter being more narrowly rounded than the dorsum. Camerae short; sutures slightly sinuous, forming shallow lateral lobes and dorsal and ventral saddles, the latter rather acute. Siphuncle cyrtochoanitic, close to concave (ventral) margin of conch, and composed of thickened, broadly expanded, two-layered segments, produced adapically into conspicuous bullettes.

The type species of *Strandoceras* is from the Lower Tretaspis limestone of the Oslo Region, and the family to which it belongs is widespread and abundant in the boreal Upper Ordovician. With the exception of *Protophragmoceras* sp., Strand, from the Sphaeronid limestone (= 4bδ) of the Oslo Region — which is probably also referable to *Strandoceras* — cyrtogomphoceratids have not previously been reported from Middle Ordovician rocks in the Scando-Baltic province.

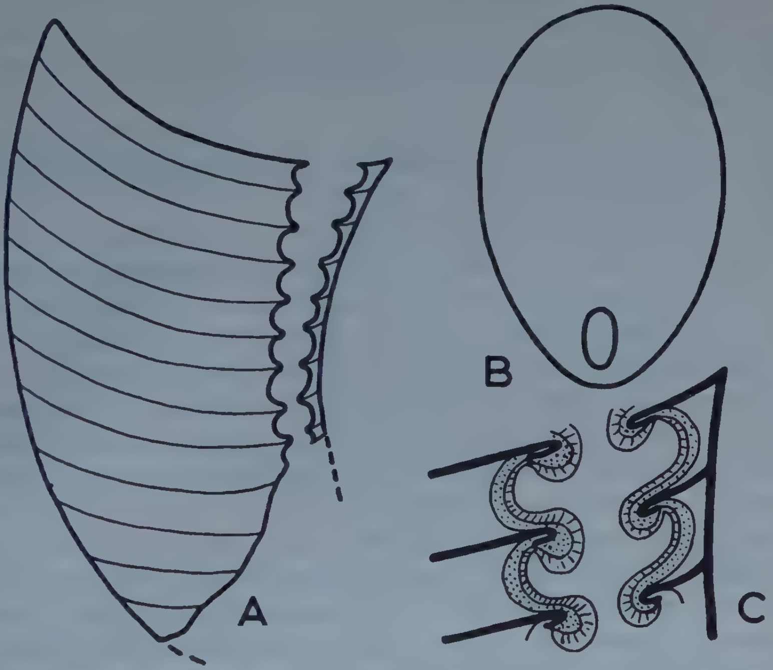

Fig. 20. *Strandoceras strandi*, n. sp. (A) Diagrammatic median dorso-ventral section through the holotype, x1. (B) Outline view of the adoral camera, x1 (venter down). (C) Enlarged schematic view of two siphuncular segments. (*See* also figure 1, Plate 21).

However, one such species is represented by a specimen from Hovindsholm, Helgøya (Nes—Hamar district) and it almost certainly came from the Cephalopod shale of probable Llandeilo age. Furthermore, this species is externally and internally similar to the holotype of *Strandoceras tyriense* (Strand) and it undoubtedly belongs in the same genus.

Strandoceras strandi Sweet, n. sp.

Plate 17, figure 4; Plate 21, figure 1; text-figure 20A—C.

Name: The specific name is in honor of Professor Trygve Strand, of Oslo University.

Type data: Holotype (P.M.O. 69307) is a partially testiferous internal mold which has been sectioned obliquely in such a fashion that the internal structures are exposed along the ventral margin of the conch.

Diagnosis: A species of *Strandoceras* which differs from the type of the genus in that it is apparently not so strongly curved and the siphuncle does not expand as rapidly orad.

Description: The holotype is partially testiferous internal mold, 45 mm long (dorsally), which represents 13 camerae of a rather strongly curved phragmocone. The conch is compressed, with lateral and dorso-ventral diameters at the adapical end of 34 and 50 mm, respectively. The cross-section is narrowly lachrymiform, the venter being more acutely rounded than the dorsum. The camerae are short, the septa are deep, and the sutures are slightly sinuous, forming shallow, asymmetrical lateral lobes, sharp-crested ventral, and more broadly rounded dorsal saddles.

Text-figure 20C is a diagrammatic dorso-ventral section through a portion of the siphuncle. From this figure, and from text-figure 20A—B, it can be seen that the siphuncle is rather large, slowly expanding adorally, and located close to the ventral, concave side of the conch. The septal necks are short and strongly recurved, but not recumbent. The connecting rings are thick, adorally adnate to the succeeding septum, broadly expanded within the camerae, and produced adapically so as to contact the adoral end of the preceding ring. Their adapical ends are swollen to form distinct pendant bullettes in the septal foramen. The structure of the two layers which form the connecting rings is difficult to determine, but both appear to be composed largely of calcareous elements, the long axes of which, in the inner layer, are oriented perpendicular to the inner surface of the outer layer.

Remarks: Strandoceras strandi, n. sp., is indeed similar to *S. tyriense* (Strand), the type of the genus, differing from it primarily in that the conch is not so strongly curved, more compressed, and the siphuncle does not enlarge so rapidly orad. The siphuncle and cross-section are different in size and proportions from *S. sphynx* (Schmidt), which is also a rather slightly curved member of the genus.

Distribution: Cephalopod shale, Hovindsholm, Helgøya (Nes—Hamar district).

Strandoceras sp.

1933. *Protophragmoceras* sp. STRAND, Norsk Geol. Tidsskr., bd. 14, p. 96—97, pl. 11, fig. 11.
1957. *Strandoceras?* sp. FLOWER, *in* Flower & Teichert, Univ. Kansas, Paleont. Contrib., Mollusca, Art. 6, p. 57.

Material: One small specimen (P.M.O. I 2392) which represents the adapical part of a curved phragmocone and has been sectioned longitudinally (in a lateral plane) so as to expose the siphuncle.

Description: The specimen to which Strand referred is the fragmentary internal mold of 8 camerae of the phragmocone. This fragment is rather strongly convex dorsally, very slightly concave ventrally and somewhat compressed in cross-section, having dorso-ventral and lateral diameters of 14.5 and 18 mm adapically, and 31 and 27 mm adorally. The dorsum is more narrowly rounded than the venter and the cross-section is broadly lachrymiform in shape. The camerae are shallow and short; the sutures are virtually straight laterally, but form prominent dorsal, and acutely rounded ventral saddles. The siphuncle is relatively large and closely approximated to the ventral margin of the conch. As in other species of *Strandoceras*, it is composed of rather long, recumbent septal necks and thick, expanded, two-layered connecting rings, the adapical ends of which, in each camera, are produced into pendant, inflated bullettes.

Remarks: This specimen is closely similar in comparable features to *Strandoceras tyriense* (Strand), the type of *Strandoceras*, and, as Strand points out (1933, p. 97), can "... hardly be distinguished from the apical part of the conch ..." of that species. The rocks from which it was collected, however, are somewhat older than are those which yielded the holotype of *S. tyriense*, so it is possible that the specimen at hand represents an undescribed species. It is not made the type of such species, however, because it is so incomplete that any diagnostic specific characters it may possess are not easily distinguishable and it would, therefore, not serve as a good type. Strand's somewhat reworded description of this specimen is included, largely for the sake of completeness, because the Sphaeronid limestone from which it was collected is now known rather certainly to be of Middle Ordovician age.

Distribution: Sphaeronid limestone, Tønnerudodden (near Gjøvik), Hadeland district. The Sphaeronid limestone is now generally considered to be Middle Ordovician and to be of the same general age as the Upper Chasmops limestone of the Oslo—Asker, Ringerike, and Hadeland (South) districts (*see* Størmer, 1953).

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PLATES 1—21

As virtually all specimens illustrated are black in color, most were coated with ammonium chloride before photographing, and the photographs were slightly retouched after the plates were assembled. The originals of specimens designated P.M.O. are in the Paleontological Museum, Oslo; those designated R.M. are in the State Museum of Natural History (Naturhistoriska Riksmuseet), Stockholm, and the numbers refer to the collections of the Paleozoological Division.

PLATE 1.

Fig. 1. *Nybyoceras holmi*, n. sp. Ventral view of the holotype, x1. Cephalopod shale, Hovindsholm, Helgøya. R.M. MO 150035—36........ (p. 46)

Fig. 2. *Cyclolituites lynnensis* (Kjerulf). Lateral view of the holotype, x1.5. Cephalopod shale, Lunder farm, Hadeland. R.M. MO 150023..(p. 154)

Fig. 3. *Diestoceras* sp. Lateral (?) view, x1.5, of a distorted specimen. Upper Chasmops limestone (4bδ), Frognøya, Ringerike. P.M.O. I 0565. (p. 91).

Fig. 4. *Vaginoceras* sp. Ventral view, x1, of a small specimen. Cephalopod shale, Hovindsholm, Helgøya. R.M. MO 87972. .... (p. 40)

Fig. 5, 7. *Bathmoceras norvegicum*. n. sp. Lateral and ventral views of the holotype, x1. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. I 1527. (p. 32)

Fig. 6. *Oncoceras* sp. Lateral view, x1.5. Horizon and locality unknown. P.M.O. I 1531. .... (p. 80)

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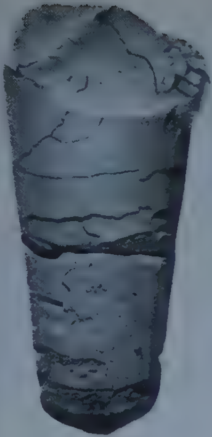
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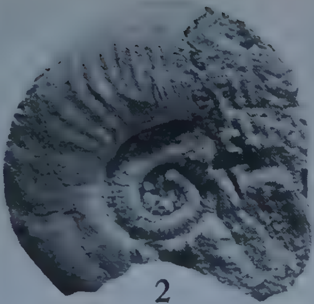
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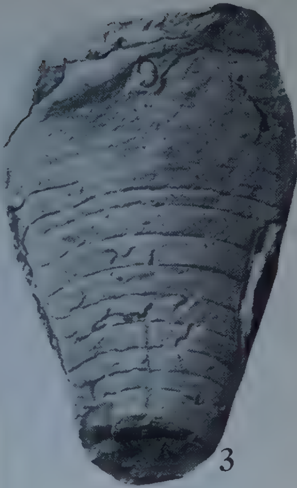
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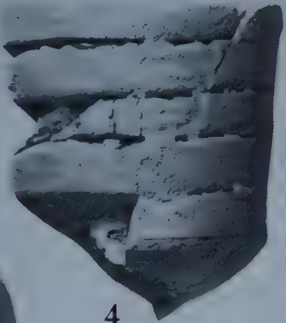
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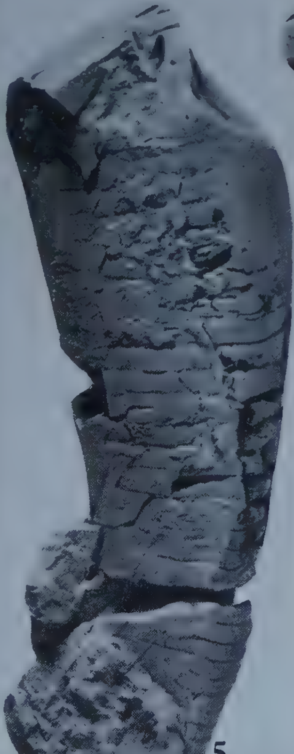
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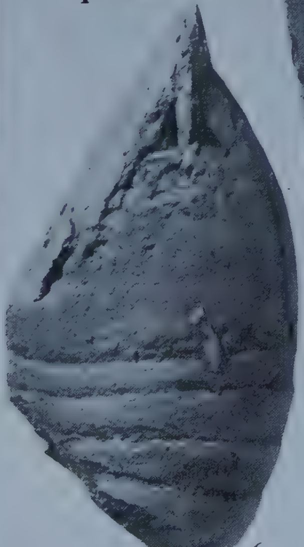
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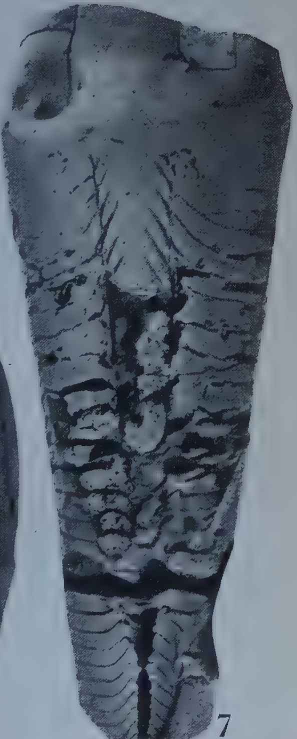
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PLATE 2.

Fig. 1, 3, 5. *Eobactrites sandbergeri* (Barrande). Ventral views, x2, of 3 conch fragments, perhaps representing parts of the same individual. Upper Didymograptus shale ($4a\alpha_{1-2}$), Bygdøy, Oslo. P.M.O. I 1812b, I 1812c, I 1812a. . . . . (p. 28)

Fig. 2. *Ctenoceras* sp. A. Ventrolateral view of an incomplete specimen, x1. Cephalopod shale, Lynne (Lunder), Hadeland. P.M.O. I 1659. . (p. 73)

Fig. 4. *Tripteroceras? problematicum*, n. sp. Ventral view of the holotype, x2. Lower Chasmops shale ($4b\alpha$) Røysetangen, Ringerike. P.M.O. I 1340. (p. 86)

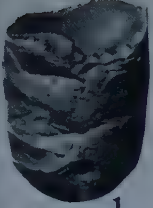
Fig. 6. *Ctenoceras* sp. A? Lateral view, x1, of a specimen of uncertain specific affinities. Horizon unknown. Hovindsholm, Helgøya. P.M.O. I 1506. (p. 73)

Fig. 7, 10. *Polygrammoceras* sp. Fig. 7 is a lateral (?) view, x1, and fig. 10 is an enlargement, ca. x3, of a part of fig. 7, to show surface sculpture. Horizon unknown. Bygdøy, Oslo. P.M.O. I 1714—15. . . . . . (p. 61)

Fig. 8. *Hoeloceras askeri*, n. sp. Ventral view of the holotype, x1. Lower Chasmops limestone ($4b\beta$) Arnestadtangen, Asker. P.M.O. 69272 . . . . (p. 56)

Fig. 9. *Dideroceras wahlenbergi* (Foord). Ventral view of an incomplete specimen, x0.5. Upper Didymograptus shale ($4a\alpha_{1-2}$), Finnmarksgate, Tøyen, Oslo. P.M.O. 69261 . . . . (p. 35)

PLATE 2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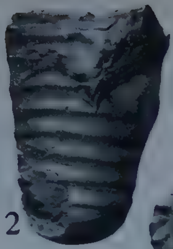
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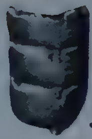
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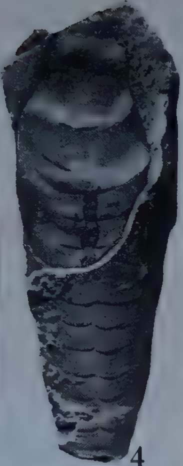
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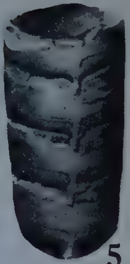
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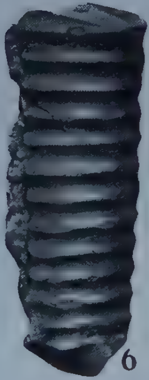
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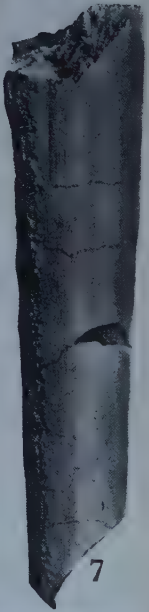
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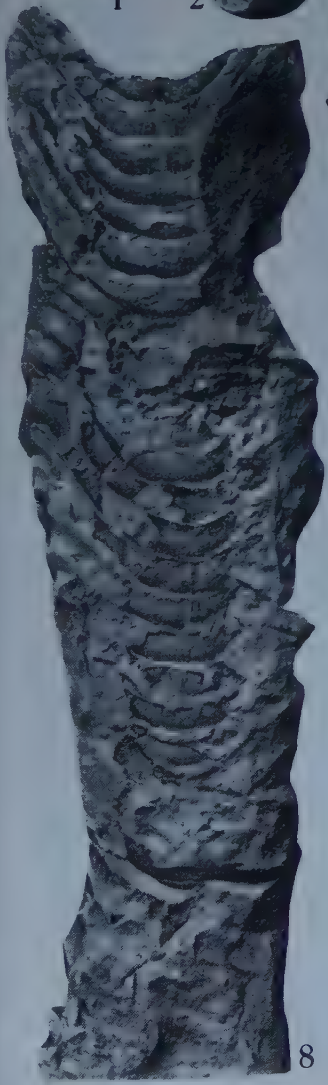
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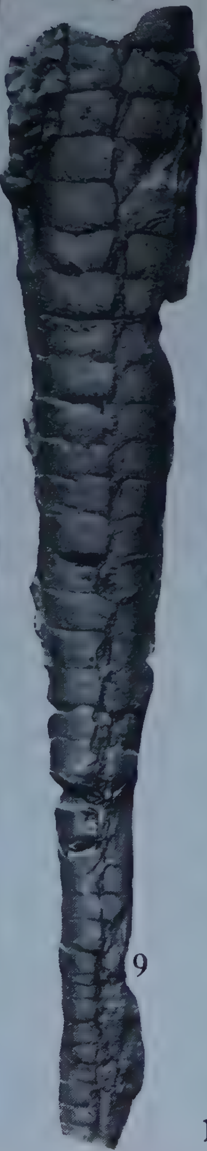
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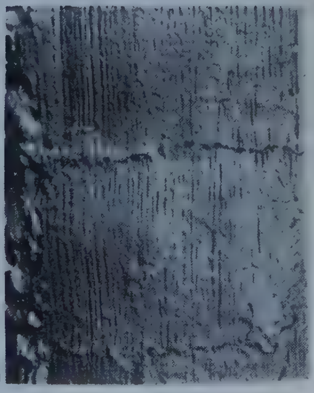
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PLATE 3.

Fig. 1. *Ctenoceras* sp. B. Enlarged view, x2, of the adapical part of a small specimen. Lower Chasmops shale (4bα), Nakholmen Island, Oslofjord. P.M.O. I 1841. .... (p. 74)

Fig. 2. *Gorbyoceras?* sp. Lateral (?) view of a fragmentary specimen, x1. Lower Chasmops shale (4bα), Volden, Asker. P.M.O. I 1846... (p. 78)

Fig. 3. *Stereospyroceras?* sp. Lateral view, x1, of a latex cast. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. I 1463...................... (p. 76)

Fig. 4. *Ctenoceras?* sp. Lateral (?) view of an incomplete specimen, x1. Ampyx limestone (?), Løken, Bygdøy. P.M.O. I 1713................ (p. 71)

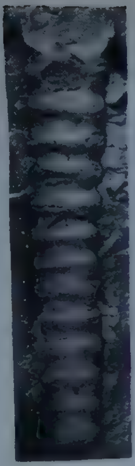
Fig. 5. *Stereoplasmoceras longicameratum*, n. sp. Lateral view of the holotype, x1. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. I 1470... (p. 64)

Fig. 6, 8, 9. *Ctenoceras* sp. A. Lateral views of 3 fragmentary specimens. Figs. 6, 8, x1.5; fig. 9, x2. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. I 1508, I 1507, and I 1505...................... (p. 73)

Fig. 7. *Allumettoceras mjoesense*, n. sp. Ventral view, x1. Cephalopod shale, Hovindsholm, Helgøya. R.M. MO 150038.................... (p. 84)

Fig. 10, 11. *Endoceras* sp. Lateral views of two incomplete specimens, x0.75. Original of fig. 10 is from Upper Chasmops limestone (4bδ), Bjerkøya; that of fig. 11 is from the Ampyx limestone (4aβ), Høvik, Bærum. P.M.O. I 1881 and 61067...................... (p. 38)

Fig. 12. *Sactorthoceras* sp. Lateral (?) view of an incomplete specimen, x1. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. I 1478—79.. (p. 60)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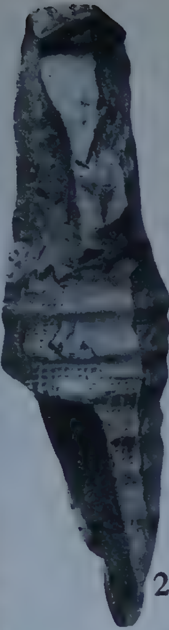
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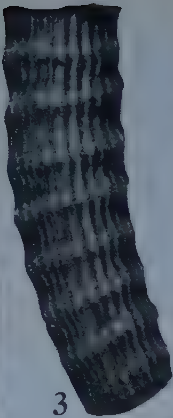
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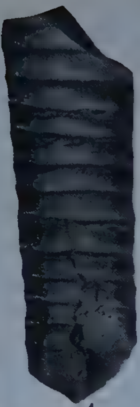
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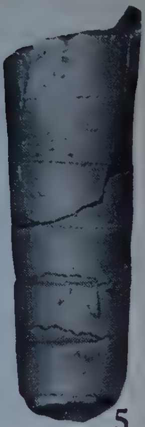
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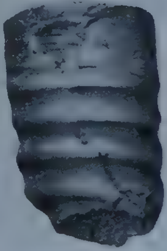
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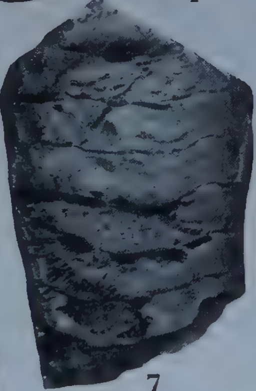
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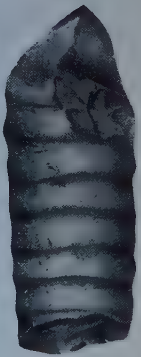
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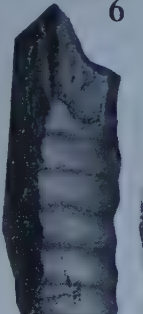
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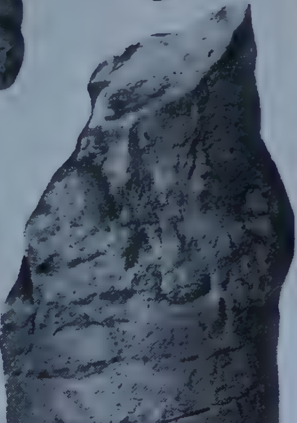
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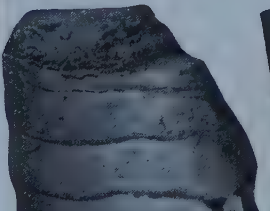
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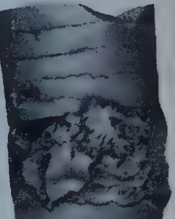
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PLATE 4.

Fig. 1. *Sactorthoceras* sp. Lateral (?) view, x1, of a specimen in which the cameral length changes abruptly. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. 62974. .... (p. 60)

Fig. 2, 3, 4. *Holmiceras kjerulfi* (Brøgger). Dorsal, lateral, and ventral views, x1, of the lectotype. Asaphus shale (3cβ) or Endoceras limestone (3cγ), Slemmestad. P.M.O. I 006 ....(p. 127)

Fig. 5. *Allumettoceras mjoesense*, n. sp. Ventral view of the holotype, x1. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. 69283...... (p. 84)

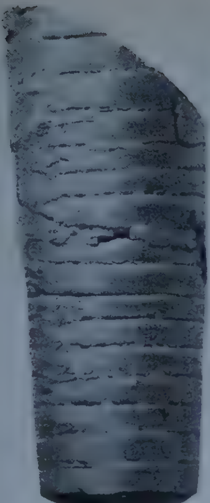
Fig. 6. *Rhynchorthoceras helgoeyense*, n. sp. Ventral view, x1, of one of the 5 syntypes. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. 69297. (p. 135)

Fig. 7. *Sactorthoceras* sp. Lateral (?) view, x0.5, of a specimen with an essentially complete peristome. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. 62973. .... (p. 60)

Fig. 8. *Stereoplasmocerina approximata*, n. sp. Longitudinal dorso-ventral polished section, x1, through the holotype. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. 69276.............................. (p. 69)

Fig. 9. *Rhynchorthoceras helgoeyense*, n. sp. Lateral view, x0.5, of a large specimen which exhibits faint traces of the retractor muscle impressions at the adapical end of the body chamber. Lower Chasmops shale (4bα) or Lower Chasmops limestone (4bβ), Bygdøy, Oslo. P.M.O. 69309. (p. 135)

PLATE 4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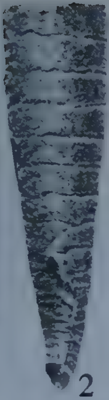
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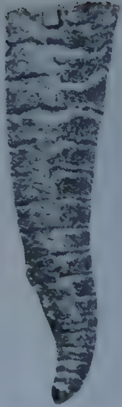
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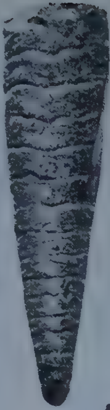
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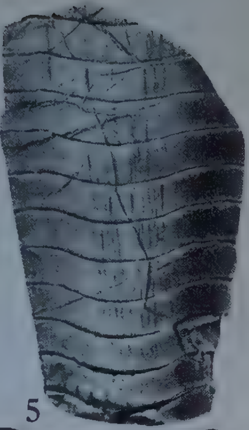
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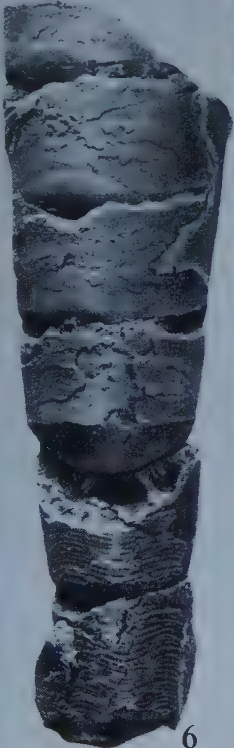
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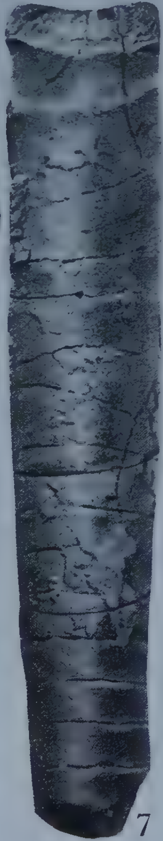
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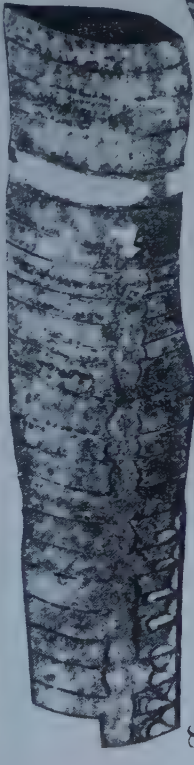
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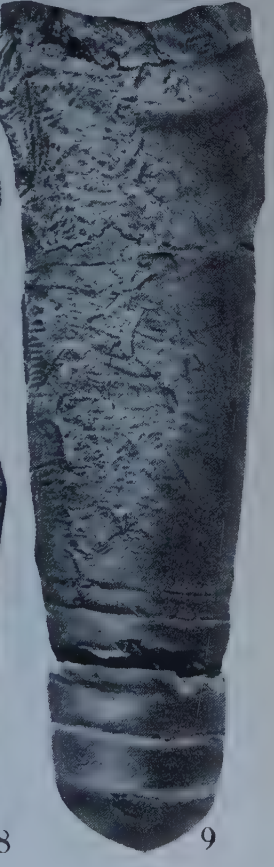
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PLATE 5.

Fig. 1. *Beloitoceras stoermeri*, n. sp. Lateral view of the paratype, x1.5. Lower Chasmops shale (4bα), Røysetangen, Ringerike. P.M.O. I 0387.. (p. 81)

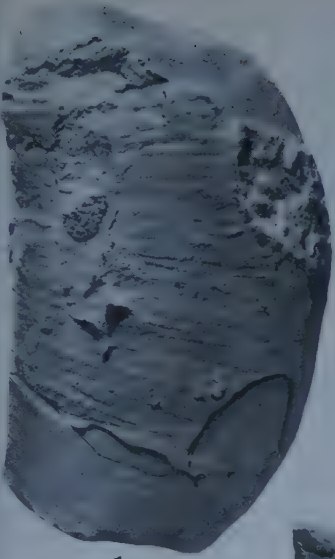
Fig. 2, 5. *Stereoplasmocerina lineata*, n. sp. Two syntypes, x1 and x1.5, respectively. Cephalopod shale, Hovindsholm, Helgøya. R.M. MO 150012, MO 150014. .... (p. 67)

Fig. 3. *Probillingsites*, n. sp. Lateral view, x1.5. Lower Chasmops limestone (4bβ), Ringsås, Ringerike. P.M.O. 8220...................... (p. 79)

Fig. 4, 7. *Nybyoceras* sp. Ventral and dorsal views of two fragmentary specimens, x1. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. I 1475 and I 1466.. (p. 49)

Fig. 6. *Valcouroceras? holtedahli*, n. sp. Lateral view of the holotype, x1.5. Cephalopod shale, Hovstangen, Gran. P.M.O. I 1669—70..... (p. 88)

PLATE 5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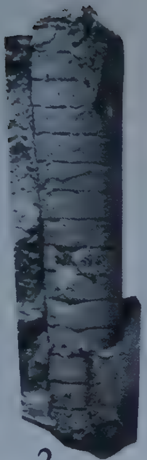
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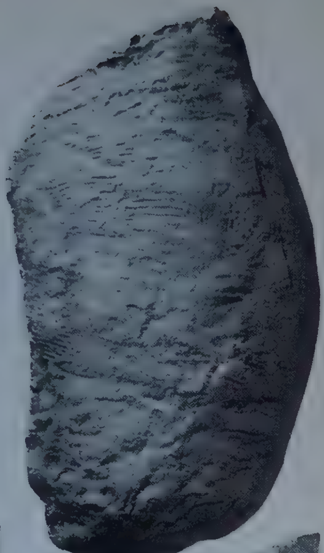
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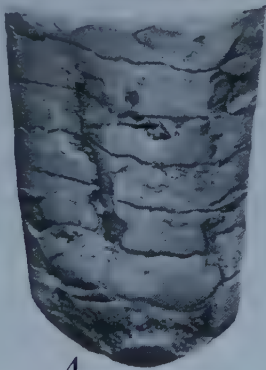
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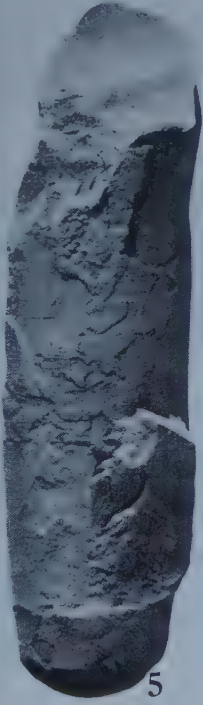
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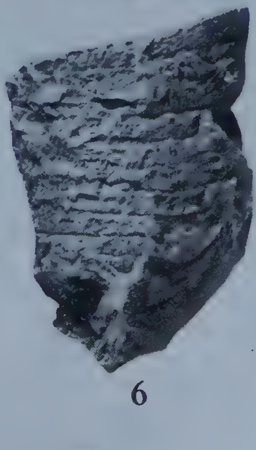
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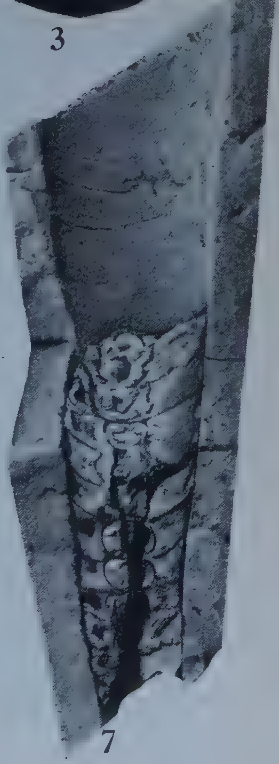
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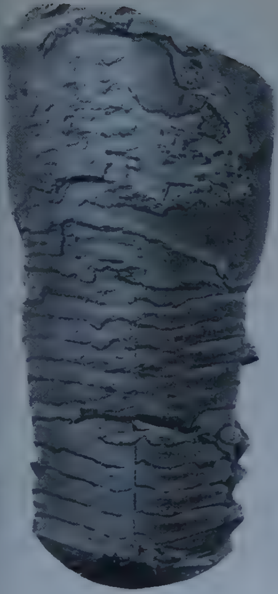
PLATE 6.

Fig. 1, 2, 3, 5, 6, 7. *Hoeloceras helgoeyense*, n. sp. Ventral views of the holotype (fig. 1, x1.5) and three additional, conspecific individuals (figs. 3, 6, 7, all x1) Fig. 2 is an enlarged view of a longitudinal dorso-ventral section through a fourth individual, and fig. 5 is a view, ca. x3, of an artificial cast of the siphuncle, prepared from the adapical part of the specimen shown in fig. 3. All four specimens are from the Cephalopod shale, Hovindsholm, Helgøya. The cast shown in fig. 4 is not catalogued; the specimens in figs. 1, 2, 3, 6, and 7 are numbered P.M.O. 69266, 69271, 69267, 69268, and 69269. .... (p. 54)

Fig. 4. *Hoeloceras askeri*, n. sp. Longitudinal dorso-ventral polished section, x1.5, through the holotype, the same specimen shown in fig. 8 on Plate 2. Lower Chasmops limestone, Arnestadtangen, Asker. P.M.O. 69272. (p. 56)

PLATE 6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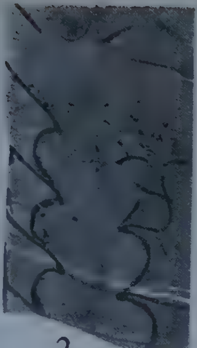
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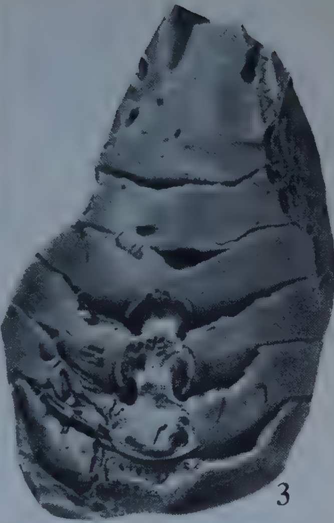
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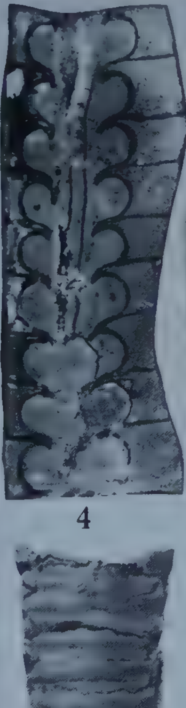
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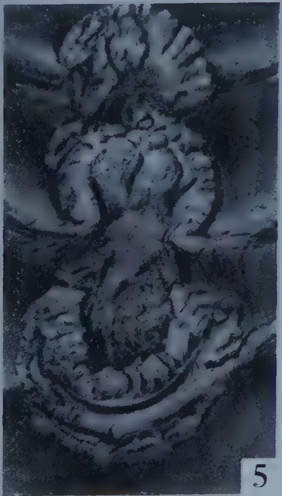
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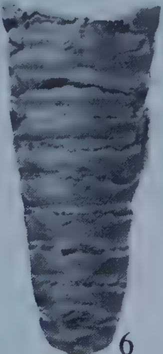
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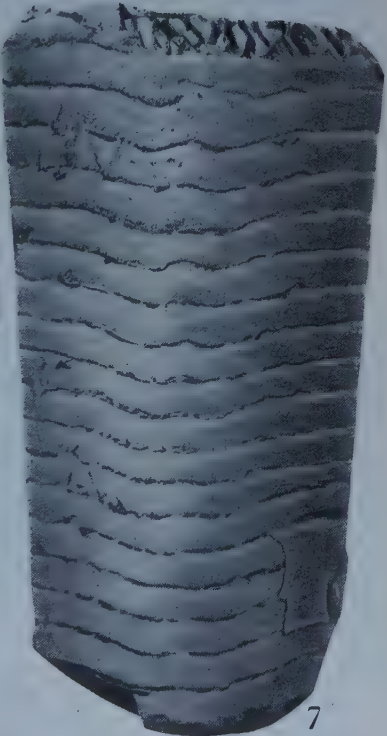
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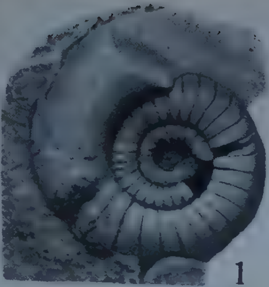
PLATE 7.

Fig. 1, 2. *Trocholites contractus* Schröder.......................... (p. 95)
Lateral view, x1.5, of a nearly complete specimen, and a dorsal view, x2, of a segment from the outermost volution of the same specimen. Cephalopod shale, Hov, Toten. P.M.O. I 1462.

Fig. 3, 4, 5, 6, 7. *Trocholites depressus* (Eichwald).................... (p. 93)
(Fig. 3) Lateral view, x2, of a distorted specimen from some part of the Ogygiocaris Series (4aα), Hamar. P.M.O. I 1460.
(Fig. 4) Lateral view, x2, of an essentially complete, slightly distorted specimen. Ogygiocaris Series (4aα) Fornebo airport, Oslo. P.M.O. I 0491.
(Fig. 5) Lateral view, x2, of an incomplete specimen from the Cephalopod shale, Hovindsholm, Helgøya. P.M.O. I 1839.
(Fig. 6) Lateral view, x2, of a nearly complete, pyritized specimen, presumably from the Ogygiocaris Series, Bakkebukt, Oslo. P.M.O. I 2407.
(Fig. 7) Natural transverse section, x3, showing shape of outer whorls. Upper Didymograptus shale (4aα_{1-2}), Huk, Bygdøy, Oslo. P.M.O. 69287.

PLATE 7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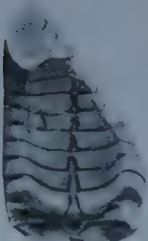
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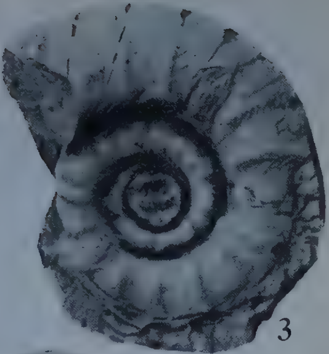
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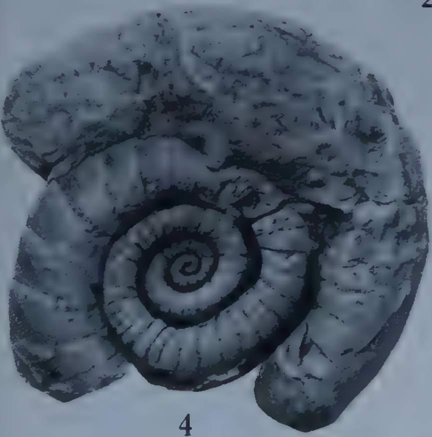
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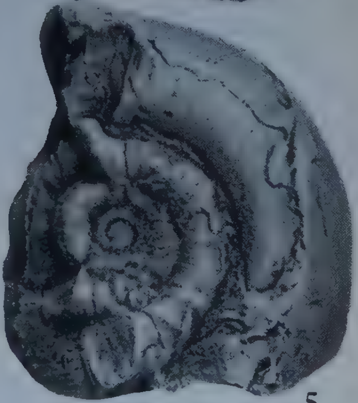
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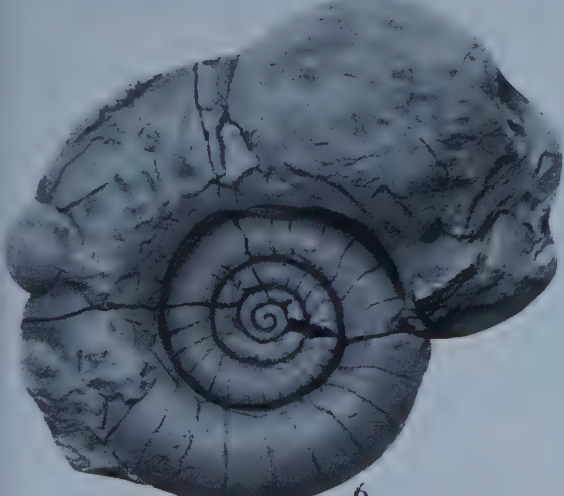
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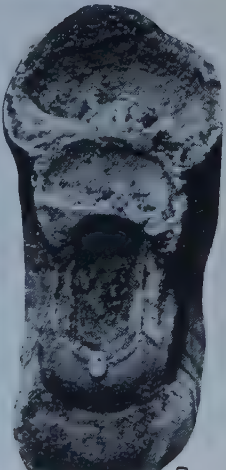
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PLATE 8.

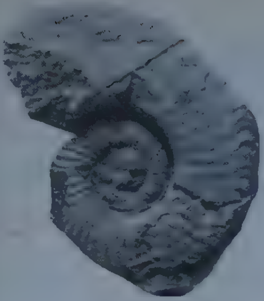
Fig. 1, 2. *Cyclolituites lynnensis* (Kjerulf). Lateral views, x1.5 and x2, of an essentially complete specimen and a body chamber showing the apertural lappets. Both specimens from the Cephalopod shale, Hovindsholm, Helgøya. P.M.O. I 1832 and I 1575. . . . .(p. 154)

Fig. 3, 5. *Trocholites hospes* (Remelé). Apertural and lateral views of the same specimen, x1. Cephalopod shale, Melbostad, Hadeland. R.M. MO 150030. . . . . (p. 96)

Fig. 4, 6. *Discoceras boreale*, n. sp. Lateral views, x1, of two incomplete specimens. The original of fig. 4 is from the Cephalopod shale, Hovindsholm, Helgøya, whereas that of fig. 6 is from an unknown horizon on Lindøya, in the Oslofjord. R.M. MO 150019 and MO 150011. (p. 105)

Fig. 7. *Discoceras arcuatum* (Lossen)? Lateral view, x1, of an artificial latex cast showing the inner whorls of an individual reminiscent of *D. arcuatum* (Lossen). (*See* Plate 12, figure 4). Float block (probably from Cephalopod shale), Toten district. P.M.O. 31171. . . . .(p. 103)

PLATE 8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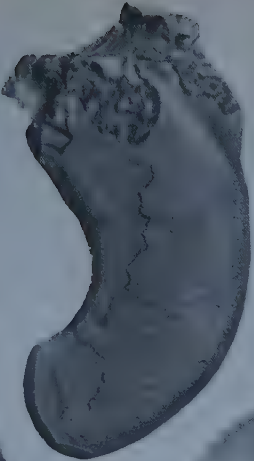
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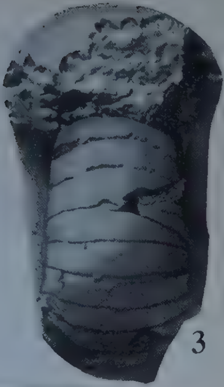
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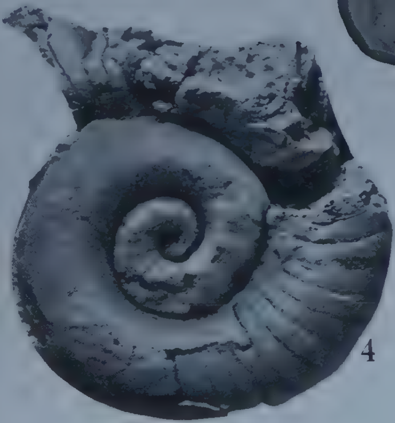
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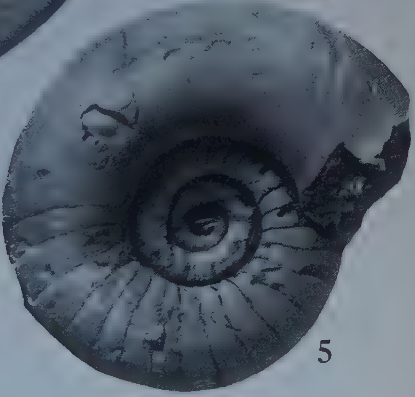
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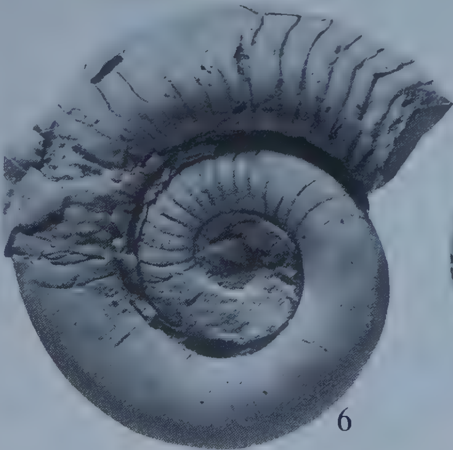
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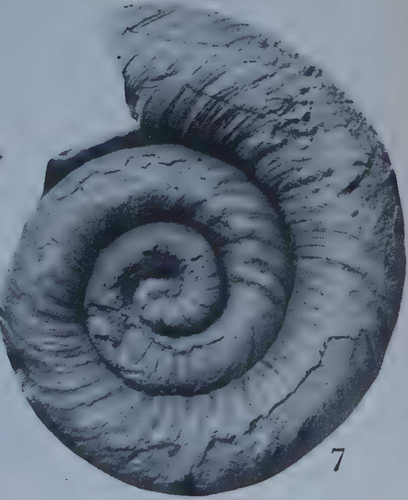
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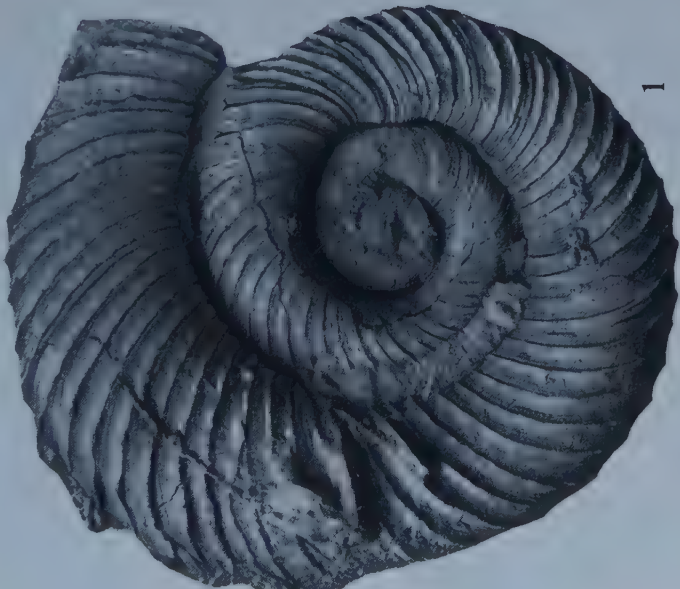
PLATE 9.

Fig. 1, 2. *Discoceras boreale*, n. sp. Lateral views, x1 and x0.5, respectively, of a latex cast showing the surface ornamentation, and of the holotype. The specimen from which the latex cast was made is from a glacial drift boulder in the Toten district; the holotype is from the Cephalopod shale at Hovindsholm, Helgoya. P.M.O. 31200 and 61428.(p. 105)

PLATE 9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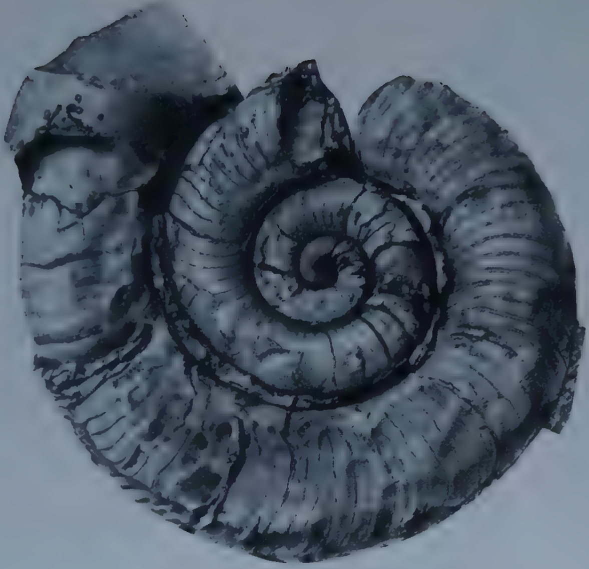
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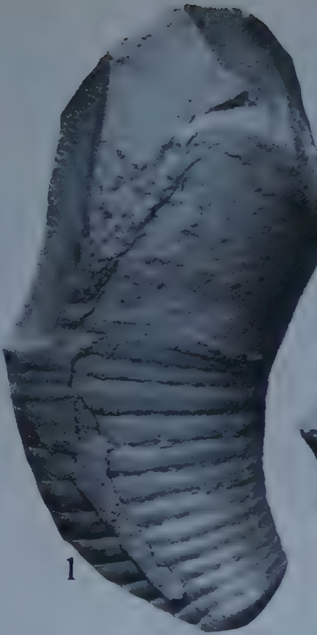
PLATE 10.

Fig. 1. Gen. & sp. indet. Lateral view, x1, of the specimen identified as *Cyrtoceras oryx* (Eichwald) by Holtedahl, 1909. Probably from Cephalopod shale in the Nes—Hamar district. P.M.O. I 1428. . . . . (p. 10)

Fig. 2, 3, 4, 5, 6. *Discoceras boreale,* n. sp. . . . .(p. 105)
(Fig. 2) Lateral view, x1, of a smlal specimen representing the innermost volutions. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. I 1838.
(Fig. 3) Septal view, x3, of a fragment from one of the inner volutions. Probably from the Cephalopod shale in the Nes—Hamar district. P.M.O. 36921.
(Fig. 4) Lateral view, x1.5, of a pyritized specimen from some part of the Ogygiocaris Series, Bygdøy, Oslo. P.M.O. I 1851.
(Fig. 5, 6) Adapertural and lateral views, x1, of an incomplete specimen from some part of the Ogygiocaris Series, Slottsbakken, Oslo. P.M.O. I 1731.

Fig. 7. *Cyrtendoceras,* n. sp. Lateral view, x1, of a specimen from the Cephalopod shale, south tip of Helgoya, Nes—Hamar district. P.M.O. I 1523. . (p. 43)

PLATE 10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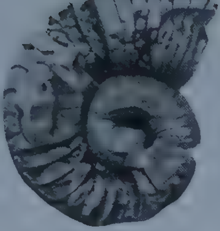
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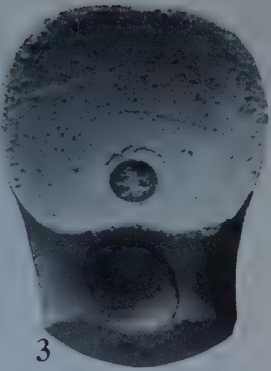
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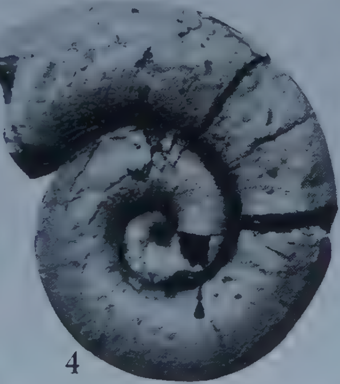
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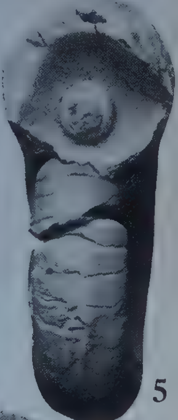
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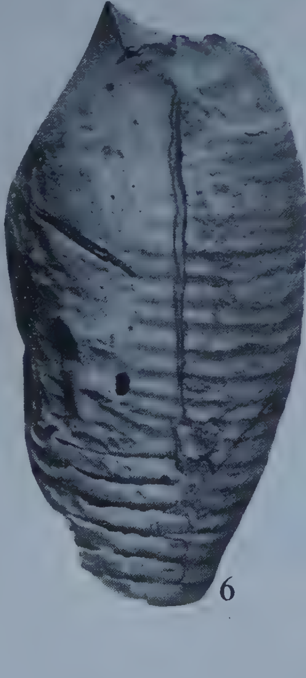
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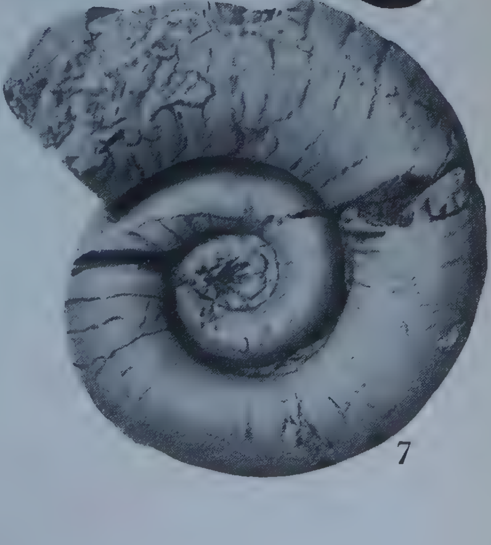
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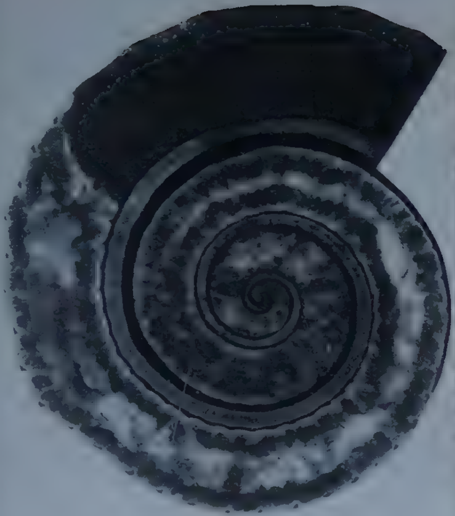
PLATE 11.

Fig. 1, 2. *Discoceras antiquissimum* (Eichwald). Fig. 1 is a longitudinal section, x1, through the siphuncle of a specimen from the Gastropod limestone (5a) of the Oslo Region. Fig. 2 is an enlargement of the inner part of Fig. 1, ca. x3.

Fig. 3. *Discoceras boreale amplicameratum*, n. sp. & subsp. Lateral view, x0.75, of the holotype. Ampyx limestone (4aβ), Fornebo airport, Oslo. P.M.O. 69308. . . . .(p. 106)

Fig. 4. *Discoceras boreale*, n. sp. Enlarged view, x4, of a thin-section of the inner two whorls of a specimen from an unknown horizon and locality. (p. 105)

PLATE 11



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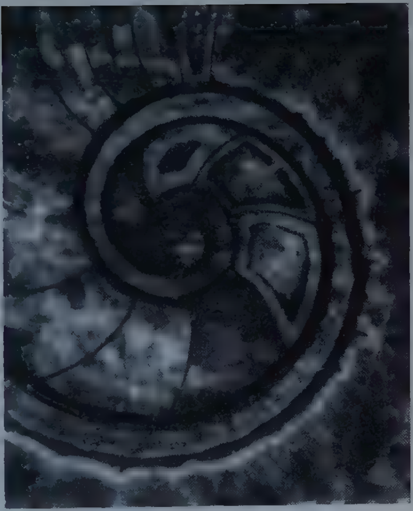

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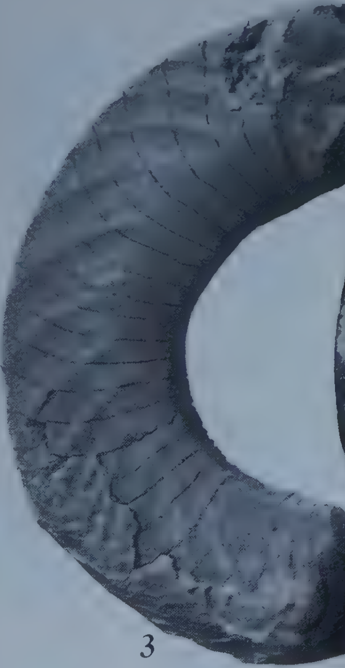

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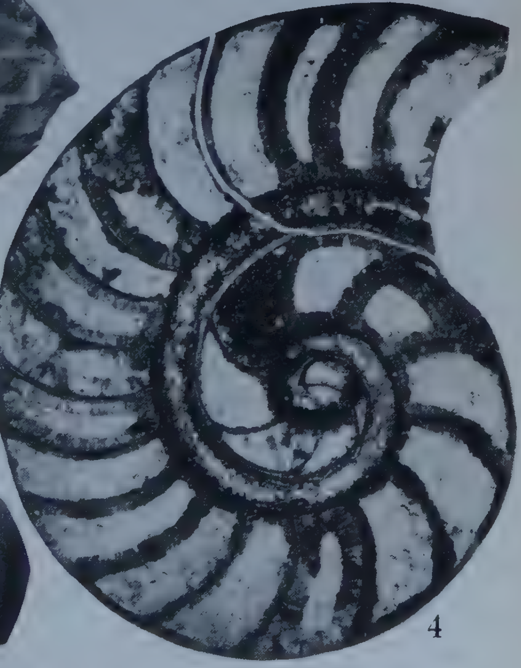

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PLATE 12.

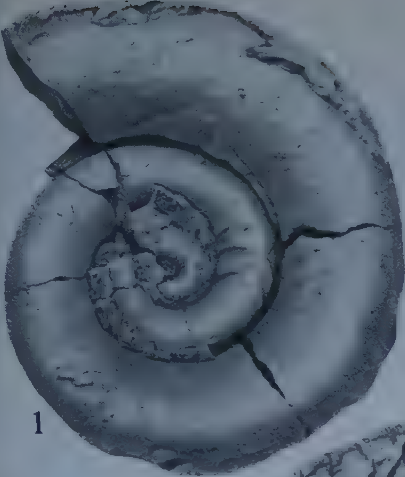
Fig. 1. *Discoceras fleischeri*, n. sp. Lateral view of the holotype, x1. Encrinite limestone, Kjørholt limestone quarry, Brevik. P.M.O. 69292...(p. 110)

Fig. 2, 3. *Discoceras ievesense* (Balaschòv). Lateral views, x0.5 and x1, of two fragmentary specimens. Lower Chasmops limestone (4bβ), Bygdøy, Oslo, and Snarøya, Oslofjord. P.M.O. I 2412 and I 0357—59..(p. 112)

Fig. 4. *Discoceras arcuatum* (Lossen). Lateral view, x1, of one of the two original types. Cephalopod shale, Billerud, Toten. Museum für Naturkunde. Berlin. ....(p. 103)

Fig. 5. *Discoceras depressum, n. sp.* Lateral view of the holotype, x0.75. Ogygiocaris Series, probably 4aα_3, Helsvær, Østre gravlund, Oslo. P.M.O. 69290. ....(p. 108)

PLATE 12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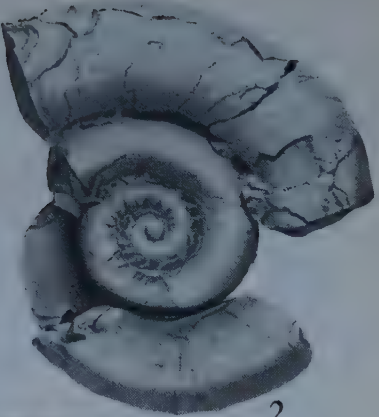
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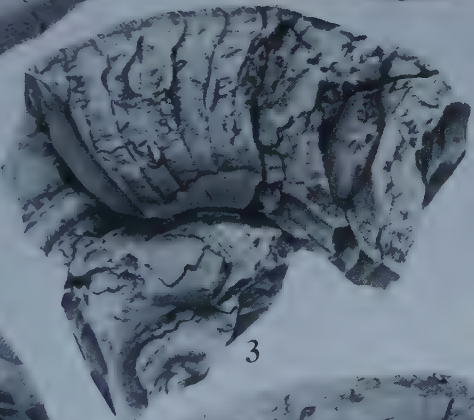
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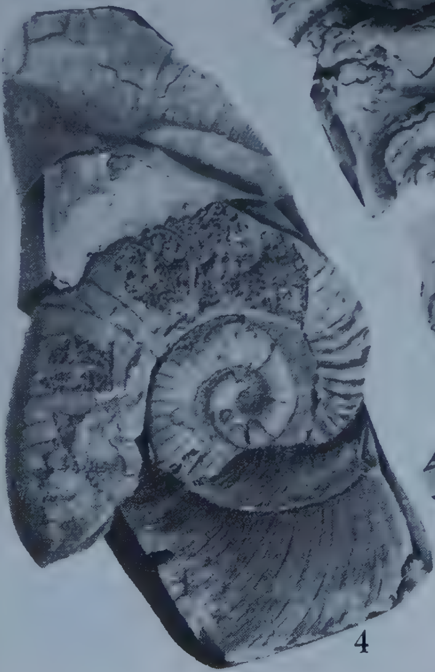
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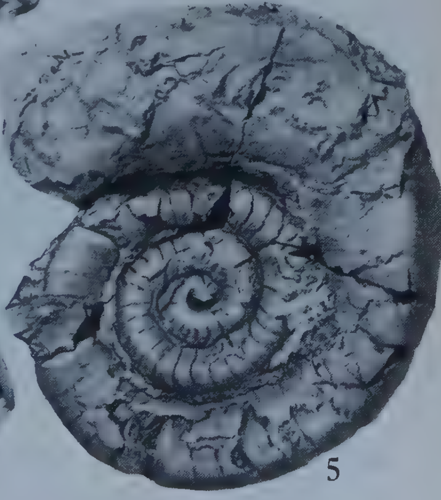
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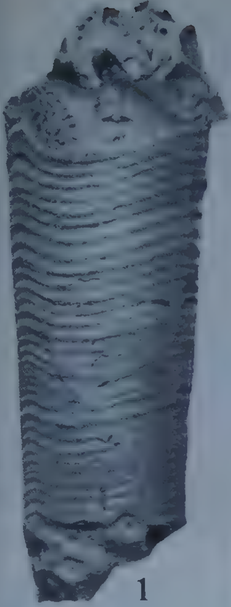
PLATE 13.

Fig. 1, 4, 6. *Trilacinoceras discors* (Holm). Figs. 1 and 4 are lateral and ventral views, x1, of the same specimen; fig. 6 is a dorsal view of a second specimen, x1. Both specimens from the same block of limestone. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. 31194...(p. 148)

Fig. 2, 3, 5. *Ancistroceras undulatum* (Boll). Fig. 2 is a lateral view, x0.5, of the adapical portion of an incomplete specimen; fig. 3 is a dorsal view, x1, of a second specimen; and fig. 5 is a lateral view, x0.75, of the most nearly complete specimen available. The originals of figs. 2 and 5 are from the Ampyx limestone (4aβ), Ostøya and Fornebo airport; that of fig. 3 is from an unspecified horizon in the Oslo district. P.M.O. 58910, I 0196, and I 0374, respectively. ..(p. 129)

PLATE 13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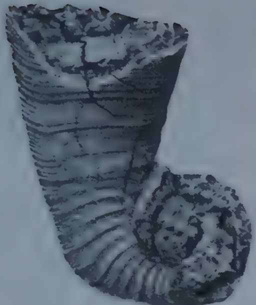
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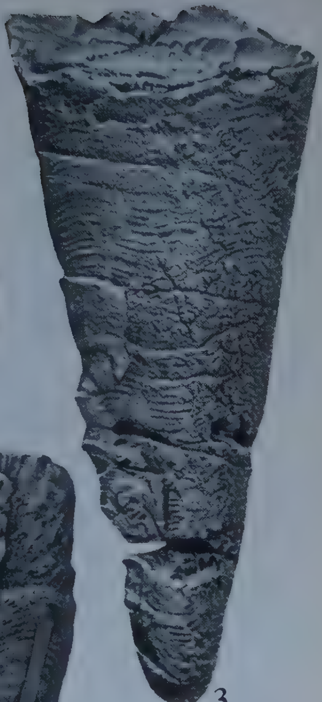
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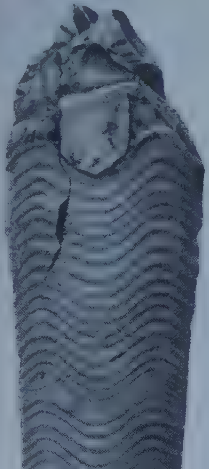
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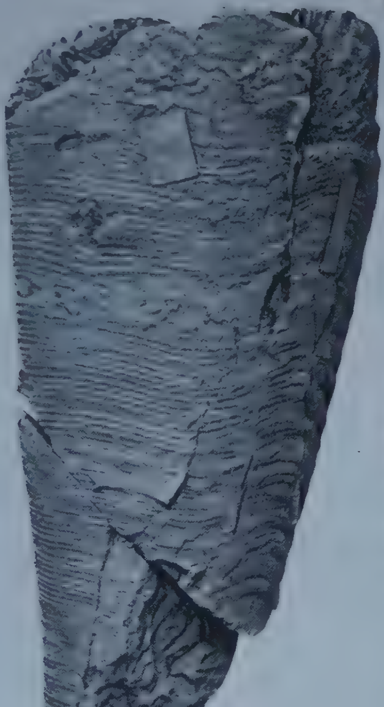
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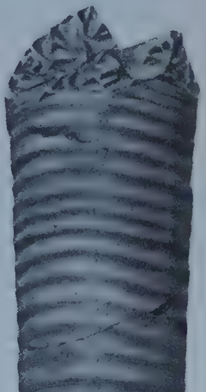
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PLATE 14.

Fig. 1. *Tyrioceras?* sp. Lateral view, x0.75, of a specimen of uncertain affinities. Lower Chasmops limestone (4bβ), Nakholmen Island, Oslofjord. P.M.O. I 1840...(p. 159)

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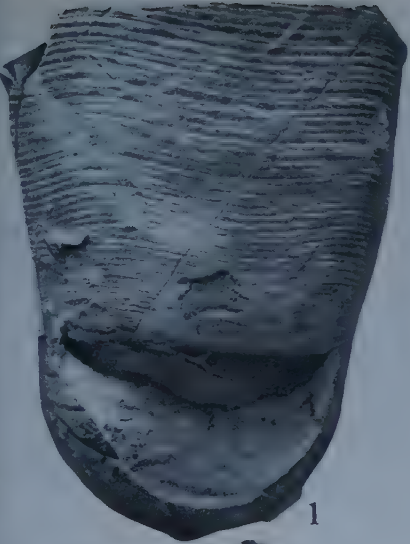
Fig. 4. *Rhynchorthoceras helgoeyense*, n. sp. Lateral view, x1, of one of the five syntypes. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. I 1538. (p. 135)

Fig. 5. *Lituites lituus* Montfort? Lateral view, x1. Ogygiocaris Series (4aα), probably 4aα_3, Engervik, Asker. P.M.O. I 0264...............(p. 142)

PLATE 14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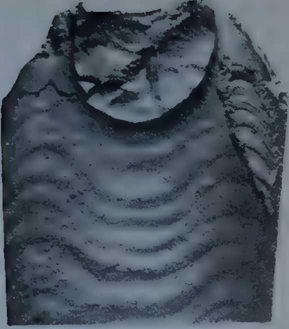
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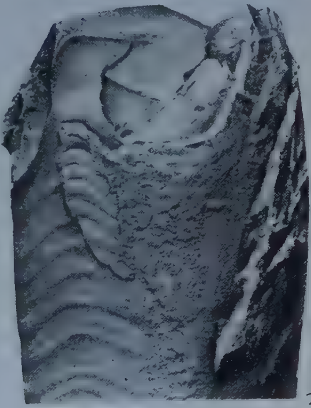
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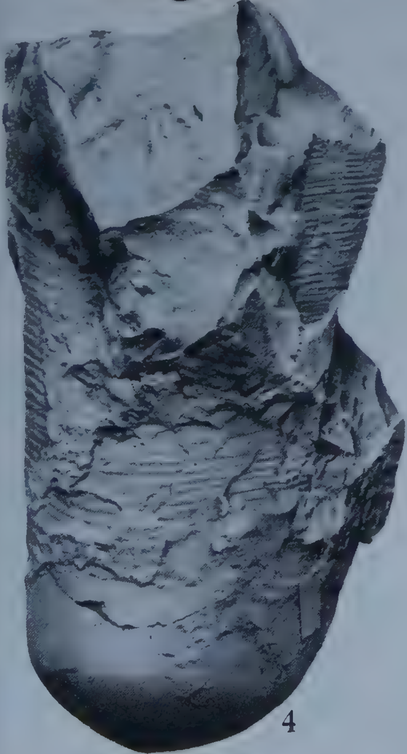
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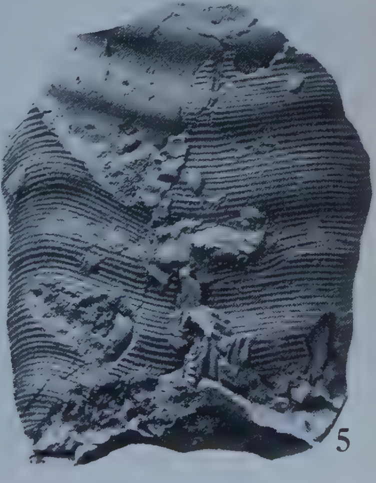
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PLATE 15.

Fig. 1, 3, 7. *Trilacinoceras norvegicum*, n. sp. Lateral, ventral, and dorsal views, x1, of the holotype. Probably from the Ogygiocaris shale ($4a\alpha_3$), at Storhamar, in the Nes—Hamar district. P.M.O. I 1578....(p. 150)

Fig. 2. "*Kionoceras*" sp. Lateral? view, x2, of a fragmentary orthoceracone of uncertain affinities. Lower Chasmops shale ($4b\alpha$), Bratterud, Ringerike. P.M.O. I 1859.................................... (p. 63)

Fig. 4. *Lituites lituus* Montfort? Ventral view, x1.? Ogygiocaris shale ($4a\alpha_3$), Hjortnestangen, Oslo. P.M.O. I 1732......................(p. 142)

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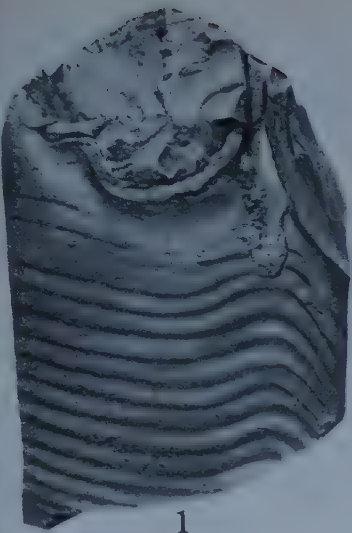
PLATE 15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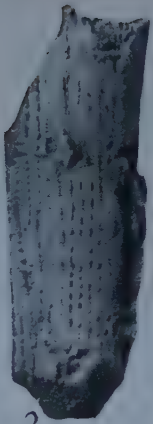
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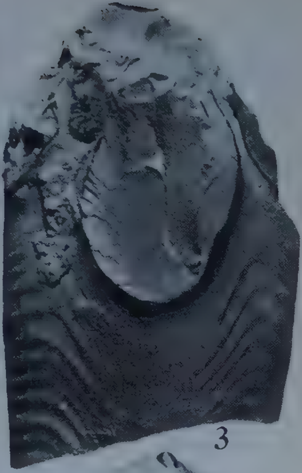
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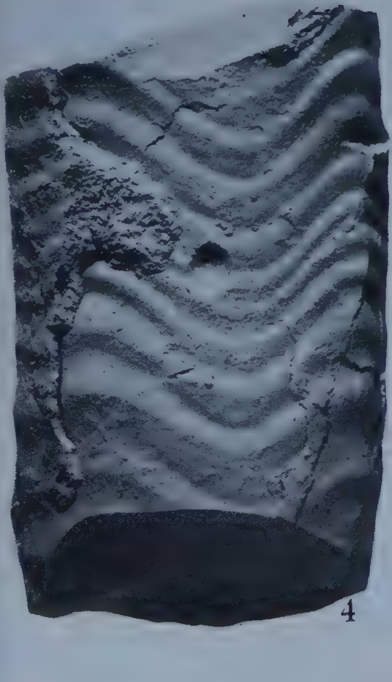
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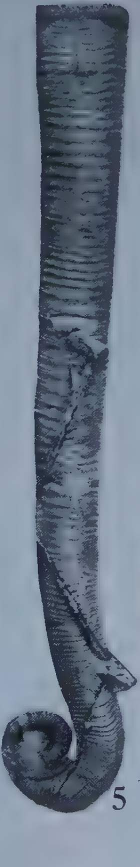
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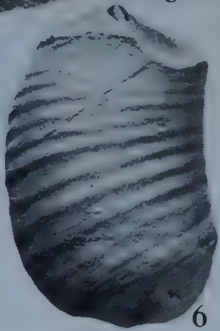
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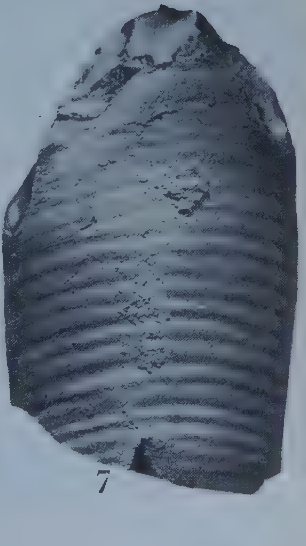
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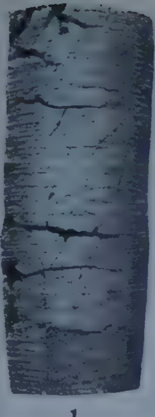
PLATE 16.

Fig. 1, 3, 7, 8, 10. *Trilacinoceras discors* (Holm). Fig. 1 is a dorsal view, x1.5, of a latex cast of part of the straight segment of a conch; figs. 3, 7, 10 are lateral views, x1.5, of latex casts of the adapical coiled segment of three additional conchs. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. I 1516, I 1563, I 1440. Fig. 8 is a lateral view, x1, of a crushed specimen which probably came from the Ogygiocaris shale (4aα_3), at the Royal Palace, Oslo. P.M.O. I 023..............(p. 148)

Fig. 2, 4. *Lituites perfectus* Wahlenberg? Lateral views, x1, of two fragmentary adapical spirals referred with question to this species. ? Ogygiocaris shale (4aα_3), Huk, Bygdøy, and Gamle Akers Kirke, Oslo. P.M.O. 69302, I 024....................................(p. 144)

Fig. 5, 6, 9. *Cyclolituites kjerulfi*, n. sp. Dorsal and lateral views, x2, of two fragmentary specimens and a lateral view, x2, of the holotype. Cephalopod shale, Lunder farm, Hadeland. R.M. MO 150029 (2 specimens) and MO 150021 (the holotype)..............(p. 157)

PLATE 16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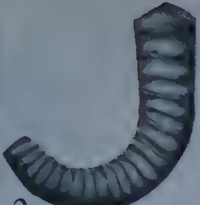
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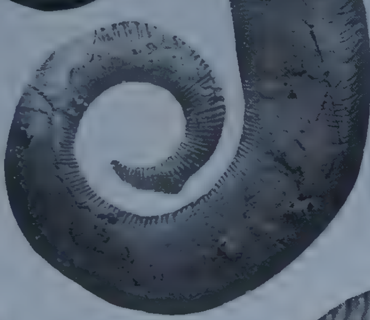
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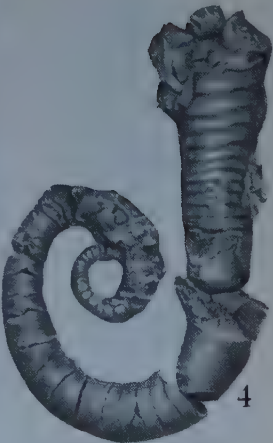
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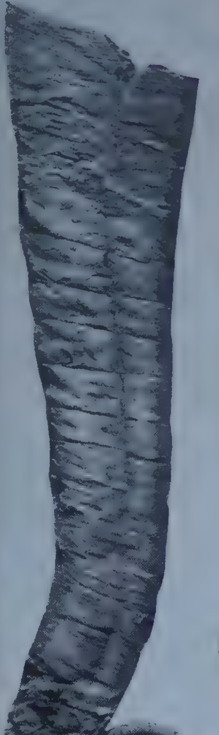
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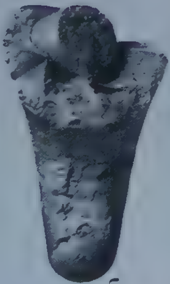
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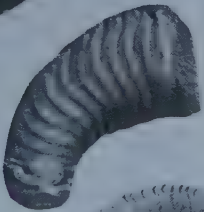
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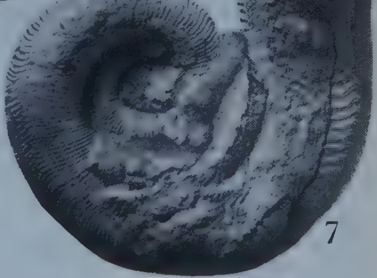
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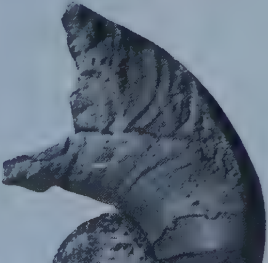
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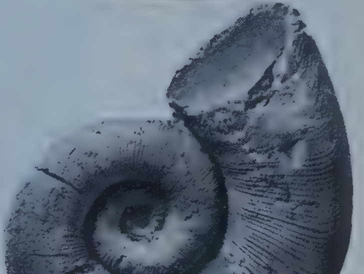
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PLATE 17.

Fig. 1. *Beloitoceras stoermeri*, n. sp. Lateral view, x1, of the holotype. Lower Chasmops shale (4bα), Bratterud, Ringerike. P.M.O. I 1860.... (p. 81)

Fig. 2. *Ruedemannoceras?* sp. Lateral view, x1, of a cyrtoceracone of uncertain affinities. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. I 2211. (p. 160)

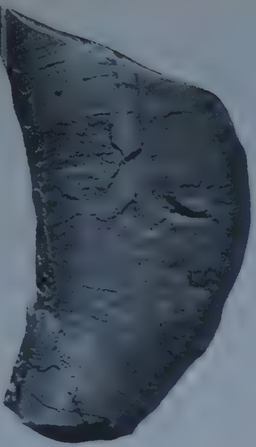
Fig. 3. *Ctenoceras* sp. A. Lateral view, x1, of an incomplete internal mold. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. 69278...... (p. 73)

Fig. 4. *Strandoceras strandi*, n. sp. Lateral view, x1, of the holotype. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. 69307.................(p. 167)

Fig. 5. *Trilacinoceras* sp. Lateral view, x0.75, of a specimen of uncertain specific affinities. ?Ampyx limestone, (4aβ), Royal Palace, Oslo. P.M.O. I 0647. ....(p. 152)

Fig. 6. *Discoceras rarospira* (Eichwald). An incomplete specimen, x1, ? from the Lower Chasmops limestone (4aβ), Blakstadtangen, Asker. P.M.O. I 2142. ....(p. 114)

Plate 17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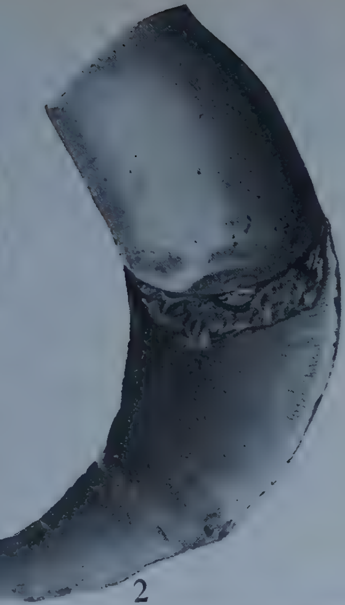
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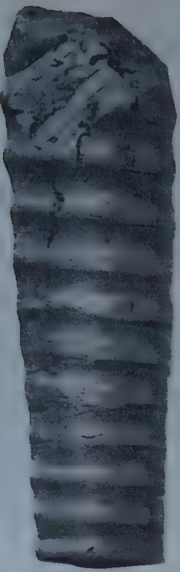
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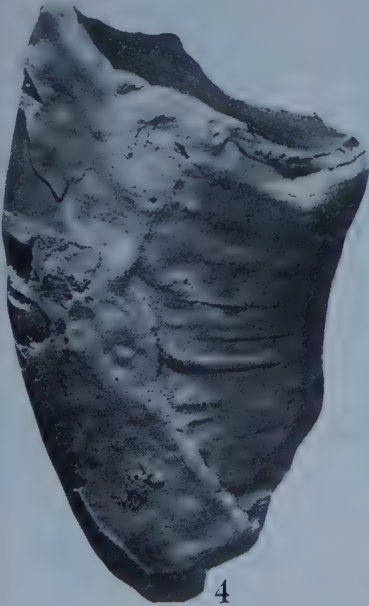
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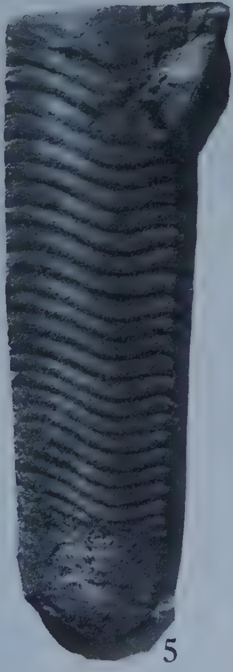
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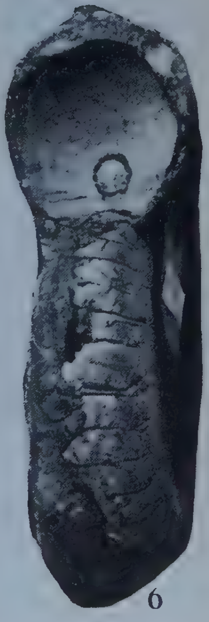
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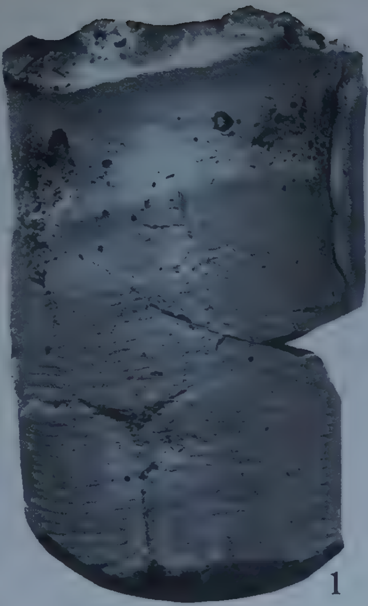
PLATE 18.

Fig. 1. *Ancistroceras undulatum* Boll? Lateral view, x0.5, of a large internal mold representing the adoral part of the body chamber and showing an essentially complete mature peristome. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. 69294............................(p. 130)

Fig. 2, 3. *Rhynchorthoceras helgoeyense*, n. sp. Lateral views, x1 and x0.5, respectively, of two syntypes. Cephalopod shale, Hovindsholm, Helgøya; and from between Nes and Ringsaker (Nes—Hamar or Ringsaker districts). P.M.O. 69298 and 19......................(p. 135)

Fig. 4, 5, 6. *Broeggeroceras? elongatum*, n. gen. & sp. Ventral, lateral, and dorsal views of the holotype, x0.75. 4cβ—4cγ, west part of Rauskjær, Vestfjorden (Oslofjord). P.M.O. 62088..................(p. 165)

PLATE 18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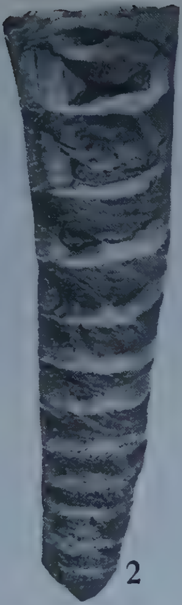
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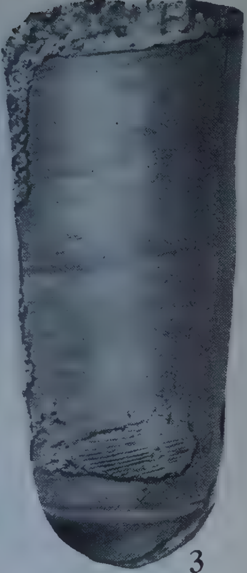
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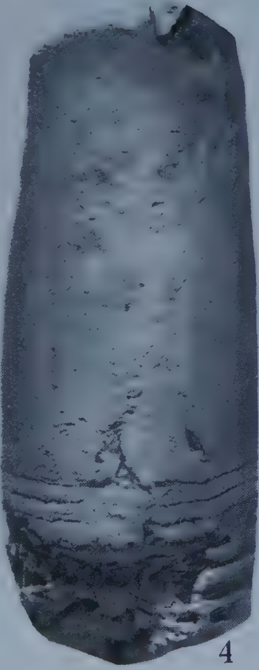
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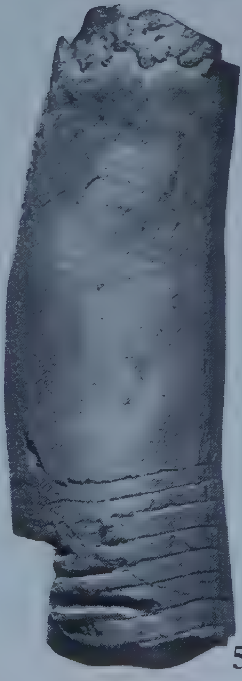
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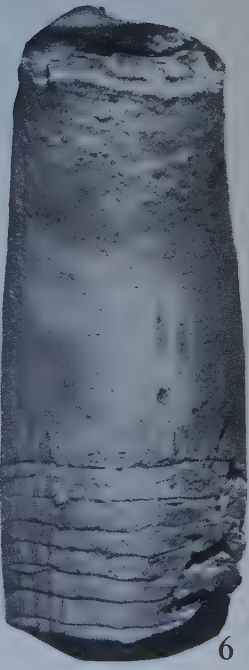
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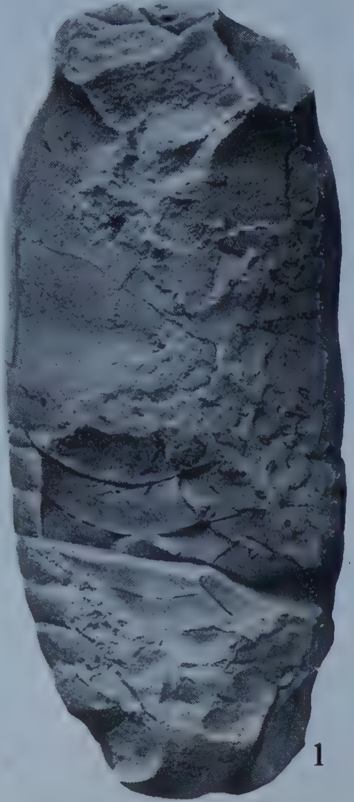
PLATE 19.

Fig. 1, 2, 3. *Broeggeroceras contractum*, n. gen. & sp. Dorsal, lateral, and ventral views of the holotype, x1. Body chamber bears an external mold of a colony of bryozoans referable to *Sagenella* [= *Berenicea*] Hall. Lower Chasmops limestone (4bβ), Nakholmen Island, Oslofjord. P.M.O. I 0346—47. . . . .(p. 162)



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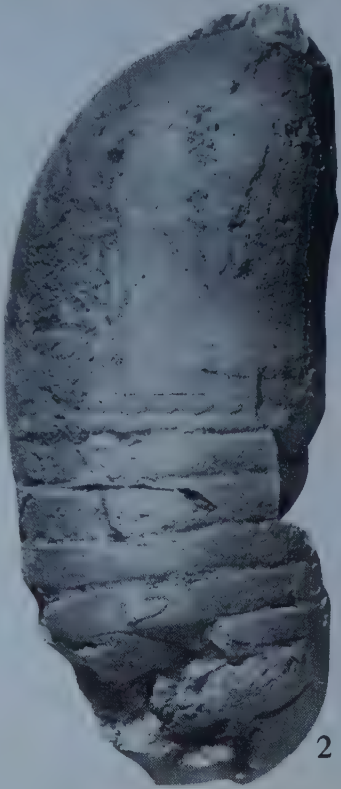

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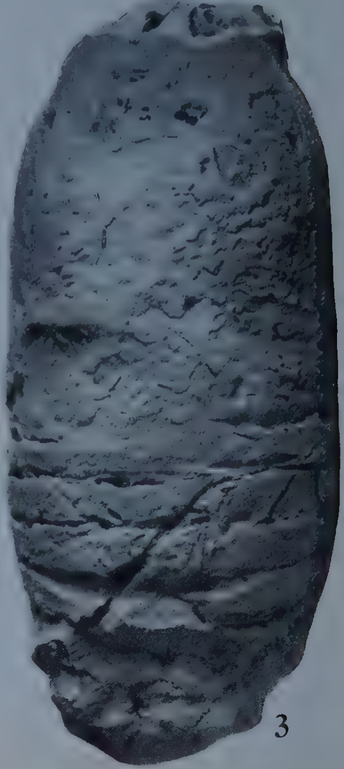

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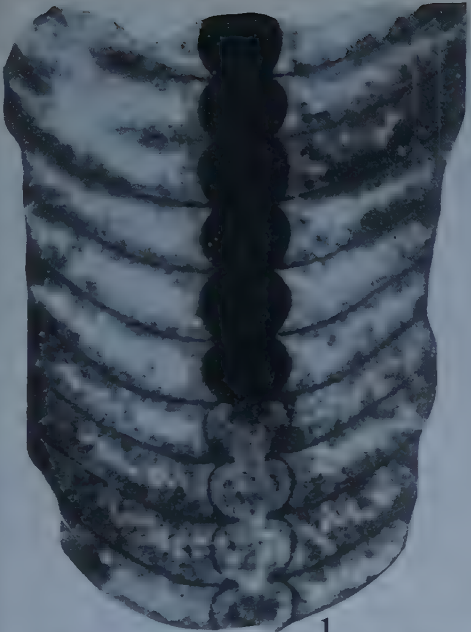
PLATE 20.

Fig. 1, 2. *Ormoceras kiaeri*, n. sp. Longitudinal dorso-ventral sections, ca. x2, through a paratype and the holotype. Mjøsa limestone, Bergvika, Helgøya (Nes—Hamar district). P.M.O. 69264. I 1602. . . . (p. 50)

Fig. 3. *Rhynchorthoceras helgoeyense*, n. sp. Enlarged view, ca. x7, of a part of a thin-section through the siphuncle of a well-preserved specimen. Note continuity of cameral and endosiphuncular deposits through break in connecting ring. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. 69310. . . . .(p. 135)

PLATE 20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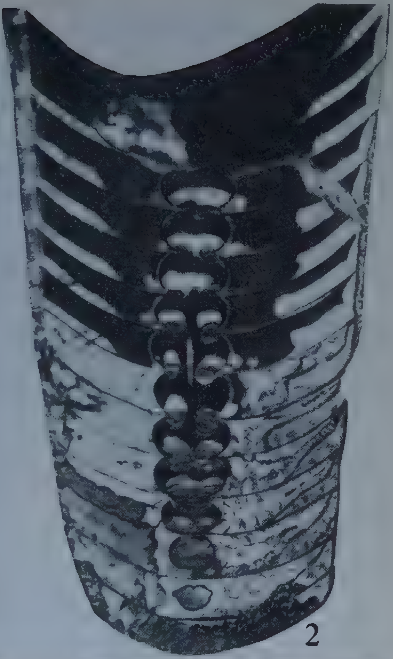
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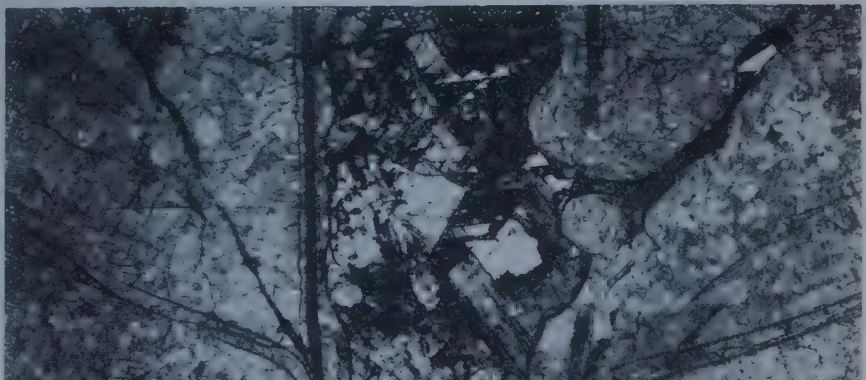
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PLATE 21.

Fig. 1. *Strandoceras strandi*, n. sp. Slightly oblique longitudinal section through the siphuncle of the holotype, x1.83. Cephalopod shale, Hovindsholm, Helgøya. P.M.O. 69307. (*see* also fig. 4, Pl. 17)..............(p. 167)

Fig. 2. *Broeggeroceras contractum*, n. gen. & sp. Longitudinal lateral section, x1.22, through the siphuncle of the holotype. Lower Chasmops limestone (4bβ) Nakholmen. P.M.O. I 0346—47. (*see* also fig. 1—3, Pl. 19). (p. 162)

Fig. 3. *Dideroceras wahlenbergi* (Foord). Longitudinally oblique dorso-ventral section, x1.8, through the siphuncle of a fragmentary specimen. Upper Didymograptus shale (4aα_{1-2}), Tøyen, Oslo. P.M.O. 69260.... (p. 35)

Fig. 4. *Nybyoceras holmi*, n. sp. Longitudinal dorso-ventral polished section through the holotype, x1.9. Cephalopod shale, Hovindsholm, Helgøya. R.M. MO 150035—36. (*see* also fig. 1, Pl. 1)................ (p. 46)

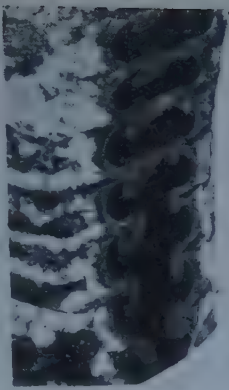
Fig. 5. *Tripteroceras? problematicum*, n. sp. Longitudinal dorso-ventral section, x1.9, through the holotype. Lower Chasmops shale (4bα), Røysetangen, Ringerike. P.M.O. I 1340. (*see* also fig. 4, Pl. 2)............... (p. 86)

Fig. 6. *Valcouroceras? holtedahli*, n. sp. Longitudinal dorso-ventral section, x1.9, through the holotype. Cephalopod shale, Hovstangen, Gran, Hadeland. P.M.O. I 1669—70. (*see* also fig. 6, Pl. 5).......... (p. 88)

Fig. 7. *Beloitoceras stoermeri*, n. sp. Longitudinal dorso-ventral setion, x1.38, through the holotype. Lower Chasmops shale (4bα), Bratterud, Ringerike P.M.O. I 1860. (*see* also fig. 1, Pl. 17)...................... (p. 81)

Fig. 8. *Ctenoceras* sp. B. Longitudinal section, x1.34, through a specimen from Slottsveien [= Karl Johans gate], Oslo, which probably came from the Lower Chasmops shale. P.M.O. I 1347—48.................. (p. 74)

Fig. 9. *Allumettoceras mjoesense*, n. sp. Longitudinal dorso-ventral section, x1.73 through a specimen from the Cephalopod shale, Hovindsholm, Helgøya. P.M.O. 69284... (p. 84)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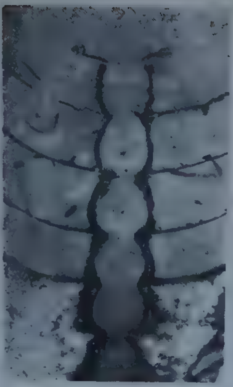
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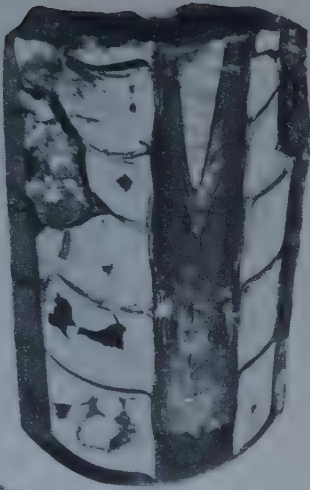
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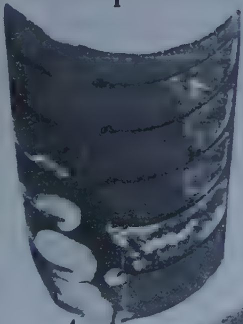
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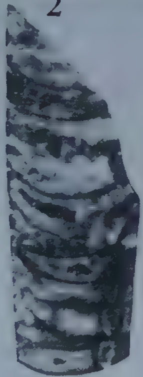
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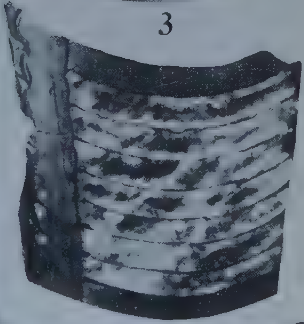
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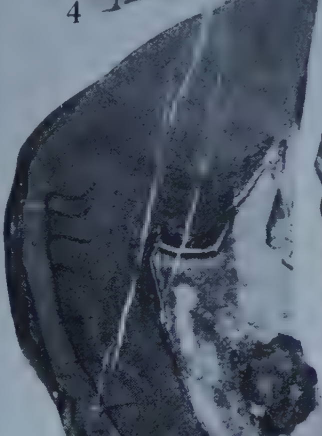
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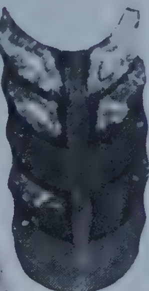
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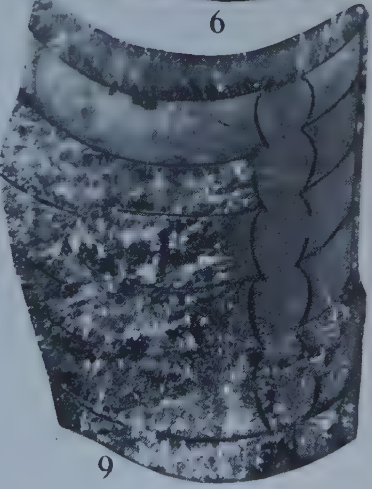
9

THE UPPER CAMBRIAN FAUNAS OF NORWAY

With Descriptions of Non-Olenid Invertebrate Fossils

BY

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Introductions and acknowledgements

The Upper Cambrian fossils in Norway occur in the Olenid Series, a sequence of black bituminous shales (alum shales) with concretions and an occasional layer of black bituminous limestone (stinkstone). The shales crop out in various districts of the Oslo region and in the belt of larger Caledonian overthrusts in southern Norway. The alum shales were easily affected by tectonic disturbances and for this reason it is hard to give the exact thickness of the Olenid Series. It is probably no more than 60 m thick in the districts of the Oslo region where it is most completely developed.

The Olenid Series in Norway is divided into 6 zones. The upper 5 of these embrace 29 subzones, whereas the lowermost zone is undivided and also is the only unit not based on an olenid. The olenids are by far the most common fossils in this series as a whole, although where they occur, *Agnostus pisiformis*, *A. obesus*, and *Orusia lenticularis* may be as numerous as any of the olenid species, whereas other fossils are rare. In addition to invertebrate fossils, some algae-like structures have also been found.

The present paper includes descriptions of the few non-olenid trilobites and non-arthropod invertebrates known from the Olenid Series in Norway. For descriptions of the olenids, and for details on the Olenid Series, the reader is referred to an earlier paper (HENNINGSMOEN, 1957b). In that paper, there is, furthermore, a discussion on the correlation of the Upper Cambrian successions in the Acado-Baltic and North American provinces. In this connection the writer would like to point out that a trilobite, described by him (1957a) as *Taenicephalus*? *peregrinus* from the *Olenus* zone in Sweden apparently belongs to the genus *Pedinocephalus* IVSHIN 1956. This genus was described from an *Aphelaspis* fauna in Kazakhstan, which supports the view that the *Olenus* zone (or a part of it) may more or less be a correlative of the *Aphelaspis* zone.

The writer wishes to thank Dr. S. Skjeseth for placing at disposal some important material from the northern districts of the Oslo region. Furthermore, the writer is indepted to Miss B. Mauritz for taking the photographs and to Dr. W. C. Sweet for reading the manuscript.

Palaeontological Museum, University of Oslo, August 1957.

Description of fossils.

TRILOBITAE

Family Agnostidae McCoy 1849

Genus *Agnostus* Brongniart 1822

Type species: – *Entomolithus paradoxus γ pisiformis* Linnæus 1757, designated by Miller, 1889.

Agnostus (*Agnostus*) *pisiformis* Linnæus 1757

Pl. 5, figs. 1–12.

1757 *Entomolithus paradoxus γ pisiformis* – Linnæus, p. 122 (Short descr.)
1878 *Agnostus pisiformis*, Ang. – Brögger, p. 46, pl. VI, figs. 13a–b. (Rough figs. of cephalon and pygidium.)
1882 *Agnostus pisifomis*, Linné – Brögger, p. 55. (Remarks.)
1891 *Agnostus pisiformis* – Andersen, p. 20. (Recorded.)
1902 *Agnostus pisiformis* – Schiøtz, pp. 5, 63. (Recorded.)
1907 *Agnostus pisiformis*, Linn. – Holtedahl, p. 14. (Recorded.)
1922 *Agnostus pisiformis* (L.) – Westergård, p. 114, pl. I, figs. 1–3. (Remarks. Figs. of cephala and pygidium.)
1923 *Agnostus pisiformis* Linné – Poulsen, p. 21, pl. I, fig. 1. (Descr. and fig. of dorsal shield.)
1929 *Agnostus pisiformis* (L.) – Strand, p. 356. (Recorded.)
1934 *Agnostus pisiformis* – Størmer, p. 333. (Listed.)
1946 *Agnostus pisiformis* (Linnaeus, 1757) – Westergård, p. 85, pl. 13, figs. 10–14. (Remarks. Figs. of cephalon and pygidia.)
1947 *Agnostus pisiformis* – Westergård, p. 4. (Suppl. descr. in connection with descr. of A. *obesus*.)

For further synonyms, see Westergård (1922) and Poulsen (1923).
Non 1865 *Agnostus* Brongn. *pisiformis* Linné – Kjerulf (= *A. obesus*.)

Type data: – A type specimen should be chosen from Swedish material.

Remarks: – In some cases the ordinary smooth-cheeked cephala are associated with cephala with grooved cheeks, as also observed in Swedish material (Westergård, 1922). Where cephala with groved cheeks occur, some of the associated pygidia have pleural lobes which are reticulated or pitted. This ornamentation is most pronounced in smaller pygidia (pl. 5, figs. 7–8). Larval cranidia have a more elongate rectangular outline than the adult cranidia. The illustrated specimen (pl. 5, fig. 12) is the smallest seen in the present material. It measures 0.5 (length) × 0.4 mm (width).

I have not been able to detect in Norwegian material the subspecies *spiniger* (DALMAN 1828), which differs in having small but distinct cephalic spines.

Occurrence: – Norway: Brevik-Skien (Rognstrand core, Ombordsnes, Skriua), Sandsvær (Sandbakk core), Eiker (Krekling, Teigen core, Stablum core, Vestfossen), Oslo-Asker (Teigen at Øyeren), Ringerike (Hval, Viul), Hamar district (Stange, Stensrudbekken), Ringsaker (Evjevika, Steinsvika, Ringstrand, Mælum), Valdres-Vardal (Nerby near Gjøvik), Østerdalen (Kakeldå). – Zone of *Agnostus pisiformis* (2aα). Alone or associated with *Olenus alpha* and *Proceratopyge nathorsti*. – Sweden (same horizon and also in the upper part of the underlying Middle Cambrian zone of *Lejopyge laevigata*), Denmark, Great Britain?, Nova Zemlya, Canada.

Subgenus *Homagnostus* HOWELL 1935

Type species: – *Agnostus pisiformis* (LIN.) var. *obesus* BELT 1867, by original designation.

Agnostus (*Homagnostus*) *obesus* BELT 1867

Pl. 5, figs. 13–16.

1865 *Agnostus* BRONGN. *pisiformis* LINNÉ – KJERULF, p. 2. (Listed.)
1867 *Agnostus pisiformis*, LIN. var *obesus* – BELT, p. 295, pl. XII, figs. 4a–d. (Descr. and rough figs. of two dorsal shields.)
1878 *Agnostus* n. sp. – BRÖGGER, p. 62.
1880 *Agnostus pisiformis* var. *socialis* – TULLBERG, p. 25. (Descr.)
1882 *Agnostus pisiformis* LINN., var. *socialis*, TULLBERG – BRÖGGER, p. 56, pl. I, figs. 10a–b. (Descr. Figs. of cephalon and pygidium.)
1890 *Agnostus pisiformis* LINNÉ var. *socialis* TULLBERG – POMPECKI, p. 15, pl. IV, figs. 24, 24a–b. (Descr. Figs. of cephalon and pygidium.)
1898 *Agnostus pisiformis* var. *socialis* – BJØRLYKKE, p. 12. (Recorded.)
1901 *Agnostus pisiformis* v. *socialis* TULLB. – MÜNSTER, p. 24. (Recorded.)
1906 *Agnostus pisiformis* (L.), var. *obesus*, BELT – LAKE, p. 9, pl. I, figs. 13–14. (Descr. Figs. of 2 dorsal shields. *A. p. socialis* is claimed to be a synonym.)
1907 *Agnostus pisiformis*, LINN. var. *socialis* TULLB. – HOLTEDAHL, p. 14. (Recorded.)
1922 *Agnostus pisiformis obesus* BELT – WESTERGÅRD, p. 116, pl. I, figs. 4a–b. (Descr. Fig. of dorsal shield. According to WESTERGÅRD, 1947, figs. 5–6 are of *A. obesus laevis* WESTERGÅRD 1947.)
1923 *Agnostus pisiformis* LINNÉ var. *obesus* BELT – POULSEN, p. 22, pl. I, fig. 2. (Descr. copied from TULLBERG, 1880. Fig. of pygidium.)

1929 *Agnostus pisiformis obesus* BELT – STRAND, p. 356. (Recorded.)
1934 *Agnostus pisiformis obesus* – STØRMER, p. 333, (Listed.)
1935 *Homagnostus obesus* (BELT) – HOWELL, p. 15, figs. 11–12. (Erects *Homagnostus*. Figs. of cephalon and pygidium from Sweden.)
?1939 *Homagnostus* cf. *obesus* (BELT) – WHITEHOUSE, p. 261, pl. XXV, figs. 17, 18? (Figs. of cephalon and pygidium.)
1947 *Agnostus* (*Homagnostus*) *obesus* BELT – WESTERGÅRD, p. 3, pl. I. figs. 10–11. (Remarks. Figs. of cephalon and pygidium.)

Type data: – One of the specimens from the Lower Lingula Flags of Wales, figured by BELT (1867), should be chosen as lectotype.

Remarks: – The Norwegian specimens agree well with the British and Swedish material. The axis of the pygidium may vary from the typical tumid and wide type (pl. 5, fig. 14) to an almost *pisiformis*-like slender type. Some well-preserved Swedish specimens (pl. 5, figs. 15–16) show that the outer surface of the test is minutely punctate. I have found no specimens in Norwegian material of the subspecies *laevis* WESTERGÅRD 1947, which was described from the zone of *Parabolina spinulosa* in Sweden.

Occurrence: – Norway: Brevik area (Rognstrand core, Saltboden core), Sandsvær (Holmesli, Krogsrud), Eiker (Krekling, Stablum core, Teigen core), Oslo-Asker (Gamlebyen in Oslo, Teigen at Øyeren), Ringerike (Hval), Valdres-Vardal (N. Gausdal, Torpa, Tonsåsen), Ringsaker (Evjevika, Ringstrand, Båshus), Østerdalen (Toten). – Zone of *Olenus* and *Homagnostus obesus* (2aβ). Alone, or associated with *Olenus gibbosus*, *O. truncatus*, *O. wahlenbergi*, or *O. attenuatus* in their respective subzones.

BRÖGGER (1882, p. 56) stated that *A. pisiformis* var. *socialis* (= *A. obesus*) also occurs with *Parabolina spinulosa*. Most probably this statement is based on a find in Ekeberg-svingen, Gamlebyen in Oslo. The find consists of three pieces of stinkstone, kept in a box with a label from BRÖGGER's time. On this label is written the locality and "2b. *Agnostus pisiformis*, Linn. var. *socialis*, Tullberg med [=with] *parabolina spinulosa*, Wahl." Both species are present, but *Parabolina spinulosa* occurs alone in one piece of stinkstone which differs lithologically from the two other pieces with *A. obesus* only. The latter does not belong to the subspecies *laevis*, and it seems probable that samples from two different horizons have been mixed together.

– Sweden (same zone. Subspecies *laevis* in the overlying zone of *Parabolina spinulosa*), Denmark (same zone), Great Britain (same horizon), Australia?

Agnostus (*Homagnostus*) *rudis holmi* WESTERGÅRD 1922

1922 *Agnostus rudis Holmi* n. var. – WESTERGÅRD, p. 118, pl. I, figs. 13–16. (Descr. Figs. of cephala and pygidia.)
1939 *Agnostus rudis* var. *holmi* (WESTERGÅRD) – KOBAYASHI, p. 168. (Assigned to *Geragnostus*.)
1947 *Agnostus* (*Homagnostus*) *rudis holmi* WESTERGÅRD – WESTERGÅRD, pp. 5, 22. (Generic reference.)

Type data: – As lectotype I select the pygidium figured by WESTERGÅRD, 1922, pl. I. figs. 15a-b, from Råbäck, Kinnekulle, Västergötland, Sweden.

Remarks: – Only a single cephalon has been found in Norway.

Occurence: – Norway: Eiker (Lunde near Vestfossen). – Zone of *Peltura minor* (2dβ), subzone of *Parabolina lobata*. Associated with *Parabolina lobata* and *Peltura scarabaeoides westergårdi*. – Sweden (same subzone and the underlying subzone of *Peltura scarabaeoides*).

Genus *Glyptagnostus* WHITEHOUSE 1936

Type species: – *Glyptagnostus toreuma* WHITEHOUSE 1936 (= *Agnostus reticulatus* ANGELIN 1851, according to WESTERGÅRD, 1947, p. 6), by original designation.

Glyptagnostus reticulatus reticulatus ANGELIN 1851

Pl. 5, fig. 17.

Non-Norwegian literature before 1947 see WESTERGÅRD, 1947.
1882 *Agnostus reticulatus*, ANG. – BRÖGGER, p. 57, pl. I, figs. 11a–b. (Remarks. Figs. of cephalon and pygidium.)
1901 *Agnostus reticulatus* ANG. – MÜNSTER, p. 24. (Recorded.)
1929 *Agnostus reticulatus* ANG. – STRAND, p. 356. (Recorded.)
1947 *Glyptagnostus reticulatus* (ANGELIN) – WESTERGÅRD, p. 5, pl. I, figs. 1–6. (Remarks on species. Figs. of cephala and pygidia.)

Type data: – As lectotype I select the cephalon figured by WESTERGÅRD, 1922, pl. I, fig. 2, one of ANGELIN'S cotypes from Andrarum, Scania, Sweden.

Remarks: – The few Norwegian specimens agree with the Swedish ones. The subspecies *G. reticulatus nodulosus* WESTERGÅRD 1947 has not been found in Norway.

Occurrence: – Norway: Ringerike (Hval, Viul), Ringsaker. – Zone of *Olenus* (2aβ), subzone of *Olenus gibbosus*. Alone or associated with *Olenus gibbosus*. – Sweden (same subzone and subzone of *Olenus truncatus*), Denmark (*Olenus* zone), Great Britain (Lower Lingula Flags), U.S.A. (Alabama), Canada (British Columbia), Australia (Queensland).

Family Asaphidae BURMEISTER 1843

Genus *Niobella* REED 1931

Type species: – *Niobe homfrayi* SALTER 1866, by original designation.

Niobella primaeva WESTERGÅRD 1909

Pl. 6, figs. 1–9.

1909 *Niobe primaeva* n. sp. – WESTERGÅRD, p. 52, pl. I, figs. 23, 24? (Descr. and figs. of incomplete cranidium and associated pygidium.)
?1909 *Megalaspis* n. sp. – WESTERGÅRD, p. 53, pl. I, fig. 25. (Descr. and fig. of small pygidium.)
1922 *Niobe primæva* WESTERGÅRD – WESTERGÅRD, p. 180, pl. II, figs. 23, 24?, not figs. 25–26. (Remarks. Figs. copied from WESTERGÅRD, 1909. Figs. 25–26 are of *Niobella aurora*, according to WESTERGÅRD, 1939.)
?1922 *Megalaspis* sp. – WESTERGÅRD, p. 180, pl. I, fig. 29. (Remarks. Fig. copied after WESTERGÅRD, 1909.)
1939 *Niobe* [*Niobella*?] *primaeva* WESTERGÅRD – WESTERGÅRD, p. 8. (Remarks.)
1947 *Niobella primaeva* (WGÅRD.) – WESTERGÅRD, p. 26. (Listed.)

Type data: – The type material, described by WESTERGÅRD (1909), comes from the *Acerocare* beds at Sandby, Scania, Sweden.

Remarks: – The type material of *Niobella primaeva* unfortunately is rather fragmentary. It seems probable that the present material belongs to this species, also because it occurs at the same horizon. According to WESTERGÅRD (1939, p. 8), the slightly older *Niobella* *aurora* differs i.a. in having a less angulate anterior margin. Apparently the present material resembles *N. aurora* in this respect. However, the pygidium differs from that of *N. aurora* in having distinct pleural furrows.

A small cranidium (pl. 6, fig. 4) shows a glabellar node. A small pygidium (pl. 6, fig. 5) resembles somewhat a pygidium (associated with *N. primaeva*) assigned by WESTERGÅRD (1909, pl. I, fig. 25) to *Megalaspis* n. sp. Also a larval pygidium (pl. 6, fig. 6) occurs in the present material. The associated hypostomes are of the *Niobella* type. The smaller one illustrated (pl. 6, fig. 8) resembles closely that of *N. aurora*, whereas the larger (pl. 6, fig. 9) has a more pointed posterior border.

Occurence: – Norway: Oslo-Asker (Nærsnes), Nes-Hamar (Røne shale quarry). – Zone of *Acerocare* (2dε), subzone of *Acerocare ecorne*. Associated with *Acerocare ecorne*, *Parabolina acanthura*, and *Pelturina punctifera*. – Sweden (same horizon).

Family Ceratopygidae RAYMOND 1913

Genus *Proceratopyge* WALLERIUS 1895

Type species: – *P. conifrons* WALLERIUS 1895, by monotypy.

Proceratopyge nathorsti WESTERGÅRD 1922

Pl. 7, figs. 2–3.

1922 *Proceratopyge Nathorsti* n. sp. – WESTERGÅRD, p. 120, pl. 2, figs. 3–5. (Descr. and figs. of pygidia.)
1947 *Proceratopyge nathorsti* WESTERGÅRD – WESTERGÅRD, p. 10, pl. 2, figs. 2–7. (Suppl. descr. Figs. of axial shield, free cheeks, cranidium, and pygidia.)
1957b *Proceratopyge nathorsti* – HENNINGSMOEN, p. 101. (Recorded.)

Lectotype: – The pygidium figured by WESTERGÅRD, 1922, pl. 2, fig. 3, designated as holotype by WESTERGÅRD, 1947, p. 10.

Remarks: – A few more or less complete free cheeks and pygidia and a small fragment of a cranidium all agree well with this species, first described from corresponding beds in Sweden. The illustrated pygidium is especially similar to the lectotype pygidium.

Occurrence: – Norway: Ringsaker (Mælum). – Zone of *Agnostus pisiformis* (2aα). Associated with *Agnostus pisiformis* and *Olenus alpha*. – Sweden (same zone.)

Family Olenidae BURMEISTER 1843.

Plates 1–4.

Remarks: – The reader is referred to an earlier paper (HENNINGSMOEN, 1957b) for descriptions of the Upper Cambrian olenids occurring in Norway. The drawings of olenids reproduced in plates 1–4 are copied from that paper, but are here arranged according to genus.

In the same paper, the collecting data for the holotype of *Pelturina punctifera* given in the description of the species (l.c., p. 250) are incorrect; – the correct data are those in the explanation of plate 28, figure 3. Furthermore, the name *Leptoplastus crassicorne* (l.c., p. 167 a.o.) should have been *Leptoplastus crassicornis*.

BRACHIOPODA

Family Billingsellidae WALCOTT & SCHUCHERT 1908

Genus *Orusia* WALCOTT 1905

Type species: – *Anomites lenticularis* WAHLENBERG 1821, by original designation.

Orusia lenticularis (WAHLENBERG 1821)

Earlier non-Norwegian references, see WALCOTT, 1912, or POULSEN, 1923.
1857 *Atrypa lenticularis* DALM. – KJERULF, p. 92. (Listed.)
1865 *Atrypa lenticularis* DALM. – KJERULF, p. 1, p. 3 (fig. 7). (Recorded. Rough figs. of dorsal and ventral valves.)
1879 *Atrypa lenticularis* – KJERULF, pl. XIII (=VI). (Listed.)
1882 *Orthis lenticularis*, WAHLENB. – BRÖGGER, p. 48. (Remarks.)
1912 *Orusia lenticularis* (WAHLENBERG) – WALCOTT, p. 765, pl. XCVIII, figs. 1, 1a–p, 2, 2a–k, 3, 3a–b, 6, 6a–c. (Descr. and figs. showing variations.)
1923 *Orusia lenticularis*, WAHLENBERG – POULSEN, p. 55. (Remarks.)
1929 *Orusia lenticularis* (WAHLENB.) – STRAND, p. 356. (Recorded.)
1934 *Orusia lenticularis* – STØRMER, p. 333. (Listed.)

Type data: – One of WAHLENBERG'S specimens from Sweden should be selected as type spesmen.

Remarks: – As discussed and illustrated by WALCOTT (1921), this species shows variations in the form of the shell and in the surface ornamentation. This is true also of the Norwegian material.

Occurrence: – Norway: Skien-Brevik (Saltboden core), Sandsvær (Sandbakk core, Gjøgrefoss), Eiker (Stablum core, Kårtveit, Krekling), Oslo (Karl Johans gate, Akersgaten, Tøyen, Gamlebyen), Modum (Fure), Ringerike (Viul, Hval), Nes-Hamar (Stange), Ringsaker (Evjevika), Østerdalen (Øksna). – Zone of *Parabolina spinulosa* (2b). Alone, or associated with *Parabolina spinulosa* ± *Protopeltura aciculata* ± *Protospongia?* sp. – Sweden (same zone), Denmark (same zone), Eastern Canada (same zone), Great Britain (Upper Lingula Flags).

Genus *Eoorthis* Walcott 1908

Type species: – *Orthis remnicha* Winchell 1886, by original designation.

Eoorthis? spp.

Pl. 7, fig. 1.

Remarks: – Three orthids possibly referable to this genus have been found at different levels in the upper part of the Upper Cambrian in Norway:

A single ventral valve, with a length of 4.7 mm and a restored width of 5.6 mm from the zone of *Peltura scarabaeoides,* lower part (2dγ), at Slemmestad (Oslo-Asker district). It is associated with *Peltura scarabaeoides scarabaeoides.*

An impression of a tiny valve (2 mm long) from the zone of *Peltura scarabaeoides*, upper part, subzone of *Parabolina* lobata (2dδ *lob.*), from Vestfossen in Eiker. It is associated with *Peltura scarabaeoides westergårdi.*

A small ventral valve (3 mm long) from the zone of *Acerocare,* subzone of *Peltura costata* (2dε *cost.*), from Vestfossen in Eiker. It is associated with *Peltura costata* and *Parabolina heres.*

Orthoid brachiopods are also recorded from the zone of *Peltura* in Sweden by Westergård (1944, p. 32).

PORIFERA

Class Hyalospongea VOSMAER 1886
Order Lyssakida ZITTEL 1877
Family Protospongiidae HINDE 1887
Genus *Protospongia* SALTER 1864

Type species: – *Protospongia fenestrata* SALTER 1864.

Protospongia? sp.

Pl. 7, figs. 4–6.

1929 *Protospongia fenestrata* SALTER – STRAND, p. 356. (Remarks.)

Material: – The material consists of a great number of isolated spicules, preserved as calcite in bituminous limestone.

Description: – The spicules are pentacts with 4 rays forming a cross and the 5th ray normal to these at their junction. The four rays are slightly curved towards the side of the shaft ray, giving the spicule a somewhat umbrella-like shape. The rays are round, very slender, and decrease slowly in size distally, but are somewhat swollen at their junction. The rays reach a length of at least 10 mm. The shaft ray appears to be as long as the others.

Discussion: – The spicules are of some interest because pentacts have not heretofore been known in protospongiids. Thus DE LAUBENFELS (1955, p. E68) remarks that "seemingly, pentact and hexact spicules had not yet evolved". Apparently the present spicules belong to a new species, probably also to a new genus. However, as long as the shape of the skeleton is not known, it seems better not to erect any new names.

Occurrence: – Norway: Ringsaker (Evjevika, Steinsodden). – Zone of *Parabolina spinulosa* (2b). Alone, or associated with *Parabolina spinulosa* and *Orusia lenticularis.*

Table 1. INVERTEBRATE FOSSILS IN THE OLENID SERIES IN NORWAY, STRATIGRAPHICALLY ARRANGED

Zones	Sub-zones	Fossils
Acerocare 2dε	ecor.	Parabolina acanthura, Acerocare ecorne, Pelturina punctifera, Niobella primaeva
	West.	Par. heres lata, Westergårdia intermedia, W. lata, W. scanica, Pelturina punctifera
	cost.	Par. heres heres, Pelture costata, Eoorthis? sp.
	trans.	Par. heres heres, Pelt. transiens, ?Acerocarina micropyga
Peltura scarabaeoides 2dγ-δ	parad.	Par. megalops, Pelt. paradoxa, ?Acerocarina granulata
	lob.	Par. lobata lobata, Par. lobata praecurrens, Pelt. scarabaeoides westergårdi, Agn. rudis holmi, Eoorthis? sp.
	linn.	Ctenopyge linnarssoni, Ct. fletcheri, Ct. pecten, Sph. humilis, Sph. majusculus, Pelt. scar. scarabaeoides
	bis.	Ct. bisulcata, Sphaerophthalmus humilis, Sph. majusculus, Peltura scarabaeoides scarabaeoides, ?Eoorthis? sp.
Peltura minor 2dβ	aff.	Ct. affinis affinis, Ct. affinis gracilis, Sphaerophthalmus alatus, Peltura minor
	tum.	Ct. tumida, Sph. alatus, Protopeltura planicauda, Peltura minor, Peltura acutidens
	spect.	Ct. spectabilis, Ct. tumidoides, Ct. angusta
	sim.	Parabolina mobergi, Ctenopyge modesta, Ct. erecta, Protopeltura bidentata

Table 1, cont.

Zones	Sub-zones	Fossils	
Protopeltura praecursor 2dα	flag.	Ctenopyge flagellifera, Ct. drytonensis, Protopeltura praecursor	
	postc.	Ctenopyge postcurrens, Protopeltura praecursor	
	negl.	Leptoplastus neglectus, Protopeltura praecursor	
	?holt.	Protopeltura holtedahli	
	?broeg.	Protopeltura broeggeri	
Leptoplastus 2c	sten.	Leptoplastus stenotus	
	ang.	Leptoplastus angustatus, Eurycare latum	
	ovat.	Leptoplastus ovatus, L. crassicornis var., Eurycare explanatum, E. latum, E. brevicauda	
	crass.	Leptoplastus crassicornis, L. norvegicus	
	raph.	Leptoplastus raphidophorus	
Parabolina spinulosa 2 b	spin.	Parabolina spinulosa, Protopeltura aciculata pusilla, Orusia lentic. Protospongia ? sp.	
	brev.	Parabolina brevispina, Orusia lenticularis	
Olenus & Agnostus obesus 2aβ	att.	Olenus attenuatus, Agnostus obesus	? in front of a name indicates, that the exact horizon is uncertain.
	wahl.	Olenus wahlenbergi, Agnostus obesus	
	trunc.	Olenus truncatus, Agnostus obesus, ?Glyptagnostus reticulat.	
	gibb.	Olenus gibbosus, O. transversus, Agnostus obesus	
Agnostus pisiformis 2aα		Olenus alpha, Agnostus pisiformis, Proceratopyge nathorsti	

Table 2. STRATIGRAPHIC AND GEOGRAPHIC OCCURENCE OF INVERTEBRATE FOSSILS IN THE OLENID SERIES IN NORWAY

Fossils	Horizon	Districts									
		Skien-Brevik	Eiker-Sandsvær	Oslo-Asker	Modum	Ringerike	Hadeland	Hamar	Ringsaker	Valdres-Vardal	Østerdalen
Trilobitae											
Olenidae											
Olenus alpha	2aα	—	—	—	—	—	—	—	+	—	—
« attenutatus	2aβ att.	—	+	+	—	—	—	—	—	—	—
« gibbosus	2aβ gibb.	+	+	—	—	+	—	—	+	+	+
« transversus	2aβ gibb.	—	—	—	—	—	—	—	+	—	+
« truncatus	2aβ trunc.	—	—	—	—	+	—	—	+	+	—
« wahlenbergi	2aβ wahl.	—	—	+	—	—	—	—	+	—	—
Parabolina acanthura	2dε ecor.	—	+	+	—	—	—	—	—	—	—
« brevispina	2b brev.	—	—	+	—	—	—	—	—	—	—
« heres heres	2dε cost.-trans.	—	+	+	—	—	—	—	+	—	—
« heres lata	2dε West.	—	—	+	—	—	—	—	—	—	—
« lobata lobata	2dδ lob.	—	+	—	—	—	—	+	—	—	—
« lobata praecurrens	2dδ lob.	—	—	+	—	—	—	—	—	—	—
« megalops	2dδ parad.	—	—	—	+	—	—	—	?	—	—
« mobergi	2dβ sim.	—	—	+	—	—	+	—	—	—	—
« spinulosa	2b spin.	+	+	+	+	+	+	—	+	—	+
Leptoplastus angustatus	2c ang.	—	+	+	+	—	—	+	+	—	—
« crassicornis	2c crass.	—	+	+	—	—	—	+	+	—	—
« crassicornis var.	2c ovat.	—	—	—	—	—	—	+	—	—	—
« neglectus	2dα negl.	—	+	+	—	—	—	—	—	—	—
« norvegicus	2c crass.	—	+	+	—	—	—	+	+	—	—
« ovatus	2c ovat.	—	+	+	—	+	—	+	+	+	—
« raphidophorus	2c raph.	—	—	+	—	—	—	+	—	—	—
« stenotus	2c sten.	—	—	+	—	—	—	—	—	—	—
Eurycare brevicauda	2c ovat.	—	+	+	—	—	—	—	—	—	—
« explanatum	2c ovat.	—	+	—	—	—	—	+	+	—	—
« latum	2c ovat.-ang.	—	+	+	+	—	—	+	+	—	—
Ctenopyge (Eoct.) angusta	2dβ spect.	—	—	+	—	—	—	—	—	—	—
« drytonensis	2dα flag.	—	—	+	—	—	—	—	—	—	—
« « flagellifera	2dα flag.	+	+	+	—	—	—	—	—	—	—
« « modesta	2dβ sim.	—	—	+	—	—	—	—	—	—	—
« « postcurrens	2dα postc.	—	—	+	—	—	—	+	—	—	—
« (Mesoct.) erecta	2dβ sim.	—	—	+	—	—	—	—	—	—	—
« « similis	2dβ sim.	—	—	+	—	+	—	—	—	—	—

ble 2, cont.

Fossils	Horizon	Districts									
		Skien-Brevik	Eiker-Sandsvær	Oslo-Asker	Modum	Ringerike	Hadeland	Hamar	Ringsaker	Valdres-Vardal	Østerdalen
enopyge (Mesoct.) spectabilis	2dβ spect.	—	—	+	—	—	—	—	+	—	—
« « tumida	2dβ tum.	—	—	+	—	—	+	—	—	—	—
« « tumidoides	2dβ spect.	—	—	+	—	—	—	—	+	—	—
« (Ct.) affinis affinis	2dβ aff.	—	—	+	—	—	—	—	—	—	—
« « affinis gracilis	2dβ aff.	—	—	+	—	—	—	—	+	—	—
« « bisulcata	2dγ bis.	—	—	—	+	—	—	—	—	—	—
« « fletcheri	2dγ linn.	—	—	+	—	+	—	—	—	—	—
« « linnarssoni	2dγ linn.	—	—	+	—	—	—	—	—	—	—
« « pecten	2dγ linn.	—	+	—	—	+	—	—	—	—	—
haerophthalmus alatus	2dβ tum.-aff.	+	+	+	+	+	+	—	+	+	—
« humilis	2dγ bis.-linn.	+	+	+	+	+	+	+	+	+	+
« majusculus	2dγ bis.-linn.	—	—	+	+	+	—	+	+	+	—
otopeltura aciculata pusilla	2b spin.	—	+	+	—	+	+	—	—	—	—
« bidentata	2dβ sim.	—	—	+	—	—	—	—	—	—	—
« broeggeri	2dα broeg.	—	+	+	—	—	—	—	—	—	—
« holtedahli	2dα holt.	—	—	+	—	—	—	—	—	—	—
« planicauda	2dβ tum.	—	—	+	—	—	—	—	—	—	—
« praecursor	2dα negl.-flag.	+	+	+	—	—	—	—	—	—	—
eltura acutidens	2dβ tum.	—	—	+	—	—	—	—	+	—	—
« costata	2dε cost.	—	+	+	—	—	—	—	+	—	—
« minor	2dβ tum.-aff.	—	+	+	—	+	—	—	—	+	—
« paradoxa	2dδ parad.	—	—	—	+	—	—	—	—	—	—
« scarabaeoides scarabaeoides	2dγ bis.-linn.	+	+	+	+	+	+	+	+	+	+
« scarabaeoides westergårdi	2dδ lob.	—	+	+	—	—	—	—	—	—	—
« transiens	2dε trans.	—	+	+	—	—	—	—	—	—	—
cerocare ecorne	2dε ecor.	—	—	+	—	—	—	—	—	—	—
elturina punctifera	2dε West.-ecor.	—	—	+	—	—	—	—	—	—	—
cerocarina granulata	2dδ parad.?	—	+	—	—	—	—	—	—	—	—
« micropyga	2dε trans.?	—	—	+	—	—	—	—	—	—	—
estergårdia intermedia	2dε West.	—	—	+	—	—	—	—	—	—	—
« lata	2dε West.	—	—	+	—	—	—	—	+	—	—
« scanica	2dε West.	—	—	+	—	—	—	—	—	—	—

Table 2, cont.

Fossils	Horizon	District									
		Skien-Brevik	Eiker-Sandsvær	Oslo-Asker	Modum	Ringerike	Hadeland	Hamar	Ringsaker	Valdres-Vardal	Østerdalen
Agnostidae											
Agnostus (Agnostus) pisiformis	2aα	+	+	+	—	+	—	+	+	+	
« (Homagnostus) obesus	2aβ gibb.-att.	+	+	+	—	+	—	+	+	+	
« « rudis holmi	2dδ lob.	—	+	—	—	—	—	—	—	—	
Glyptagnostus reticulatus	2aβ trunc.?	—	—	—	—	+	—	—	+	—	
Asaphidae											
Niobella primaeva	2dε ecor.	—	—	+	—	—	—	+	—	—	
Ceratopygidae											
Proceratopyge nathorsti	2aα	—	—	—	—	—	—	—	+	—	
Brachiopoda											
Eoorthis? sp.	2dε cost.	—	+	—	—	—	—	—	—	—	
Eoorthis? sp.	2dδ lob.	—	+	—	—	—	—	—	—	—	
Eoorthis? sp.	2dγ	—	—	+	—	—	—	—	—	—	
Orusia lenticularis	2b brev.-spin.	+	+	+	+	+	—	+	+	—	
Porifera											
Protospongia? sp.	2b spin.	—	—	—	—	—	—	—	+	—	

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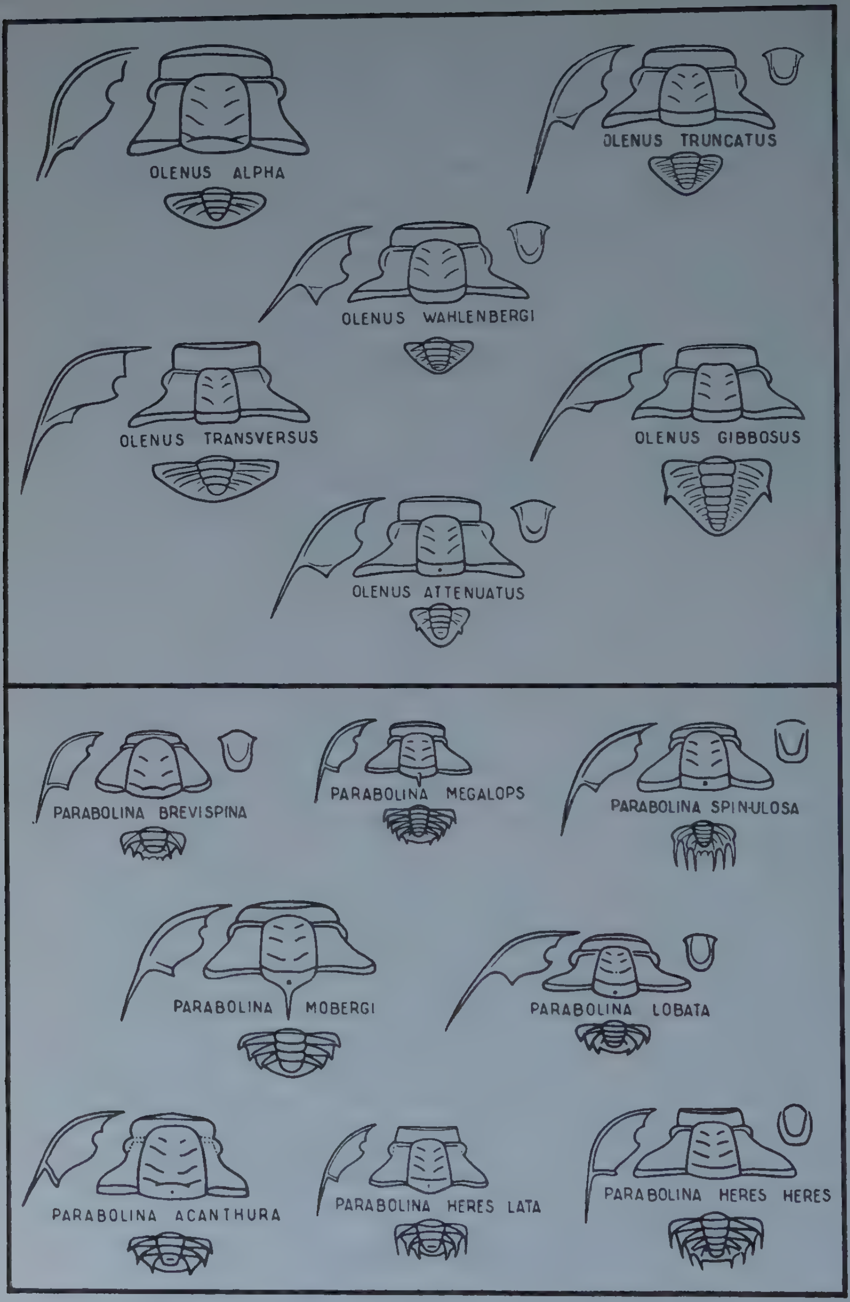
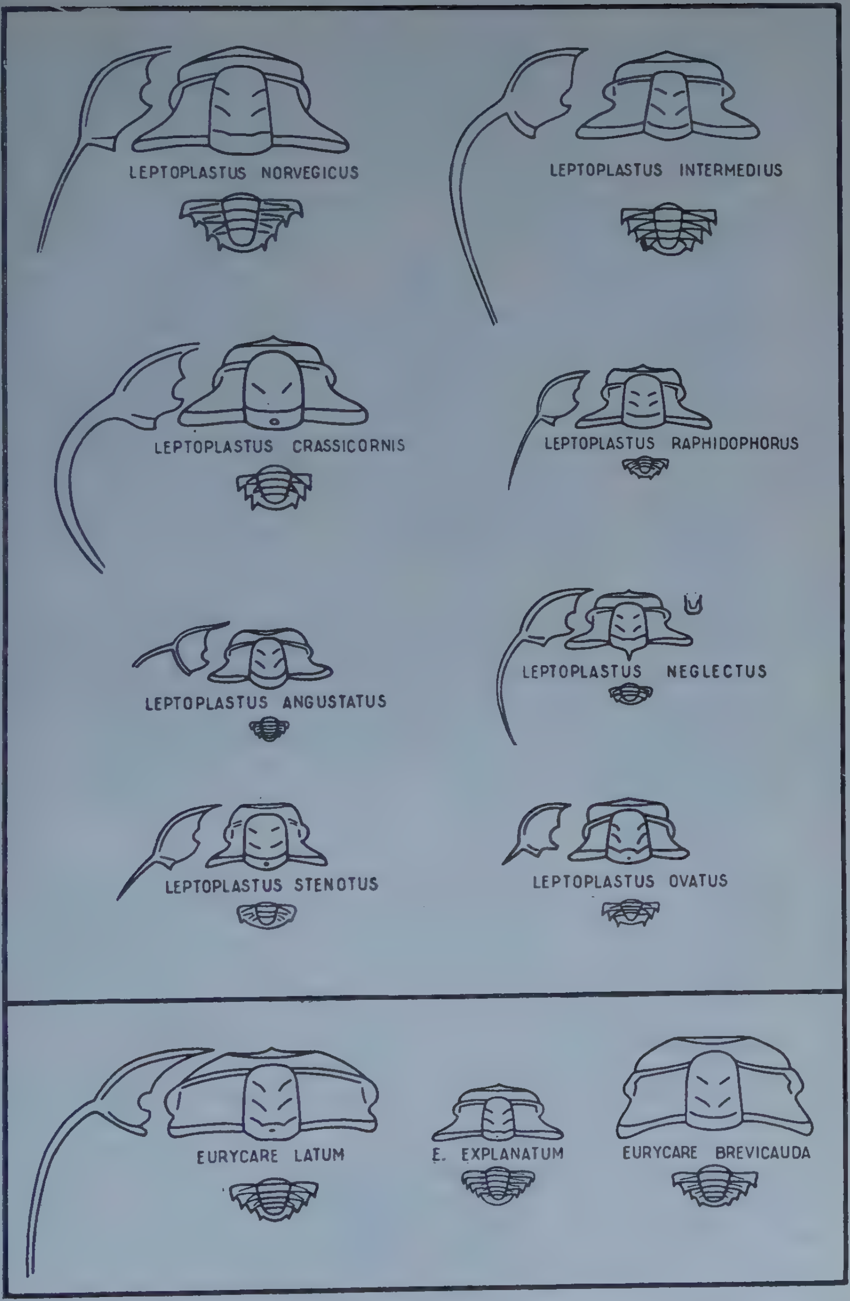
PLATES 1—7

PLATE 1

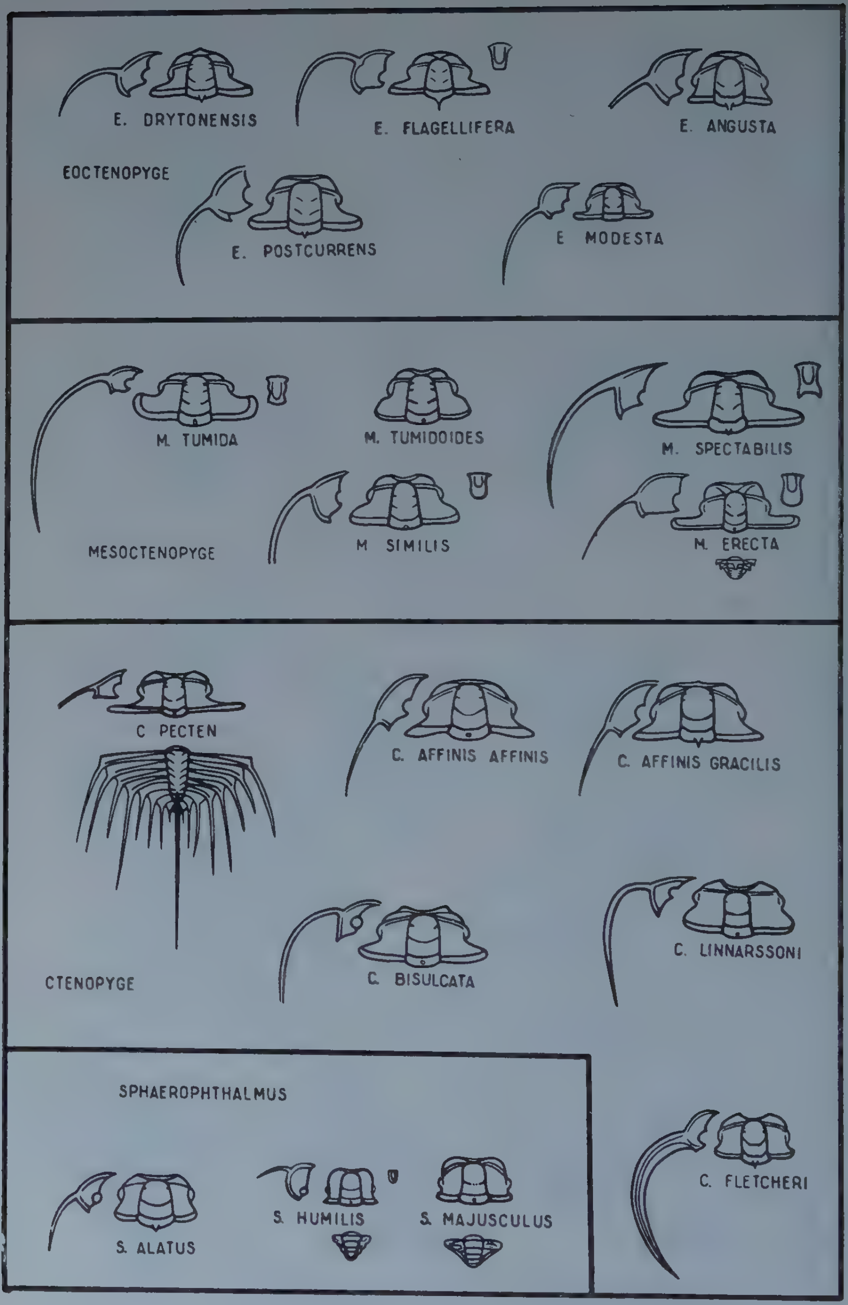


Olenidae; Oleninae. (C. x 2)



Olenidae; Leptoplastinae 1. (C. x 2)

PLATE 3



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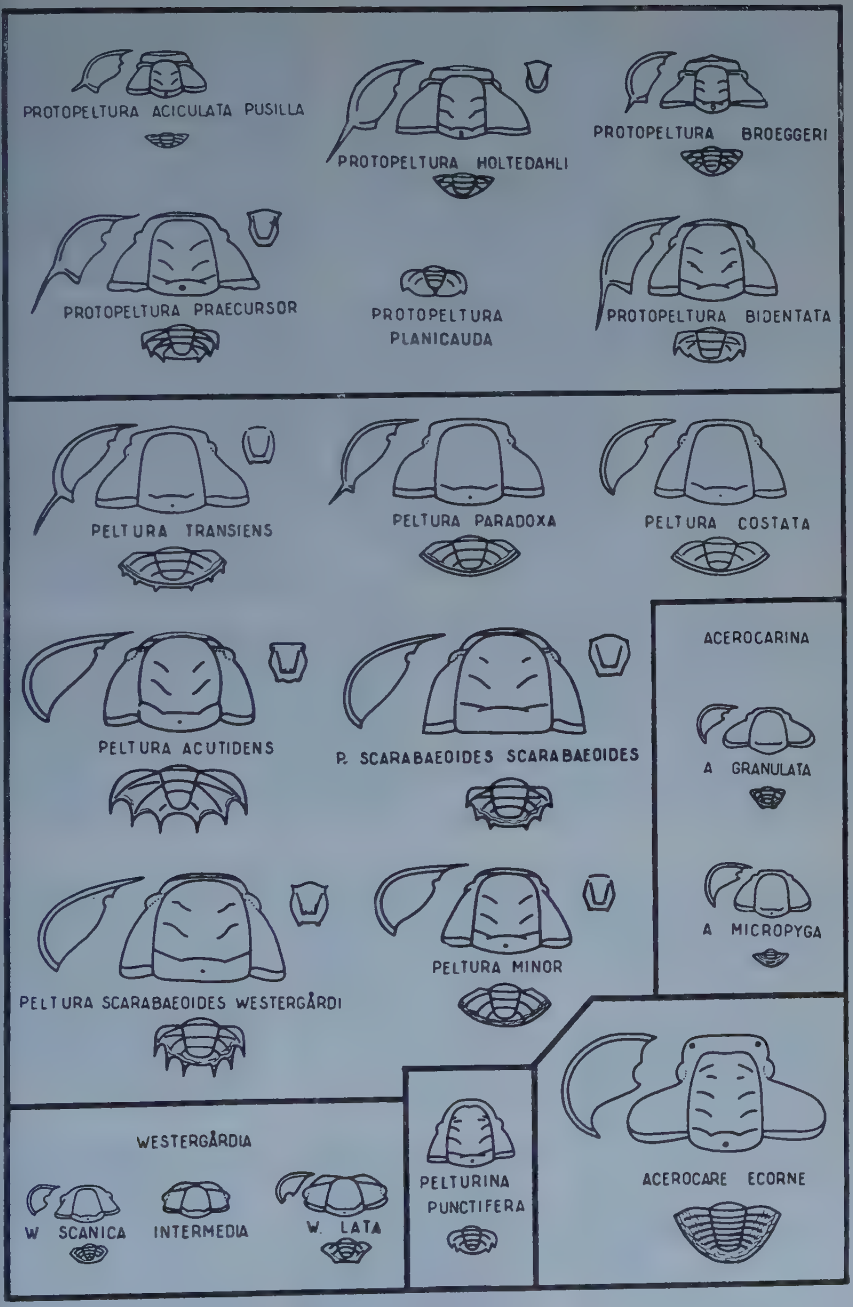


Olenidae; Pelturinae. (C. x 2)

PLATE 5

The photographs are not retouched. The specimens were whitened with ammonium chloride.

All x 6.6

Agnostus (*Agnostus*) *pisiformis* LINNÆUS 1757 – p. 181

2aα. Mælum, Ringsaker. Coll.: S. Skjeseth, 1949.

Fig. 1. Well-sized smooth cephalon (P.M.O. no. 66765).
Fig. 2. Well-sized smooth pygidium (P.M.O. no. 66763).

2aα. Skårås, Valset, Nes-Hamar. Coll.: S. Skjeseth, 1950.

Fig. 3. Smooth cephalon (P.M.O. no. 67761a), showing well the posterior border.
Fig. 9. Smooth pygidium (P.M.O. no. 67761d), showing well the marginal spines.
Fig. 10. Smooth pygidium (P.M.O. no. 67761b).
Fig. 11. Thoracic segment (P.M.O. no. 67761c).

2aα. Stensrudbekken, just east of Stensrudtjernet, Nes-Hamar.
Coll. S. Skjeseth, 1950.

Fig. 4. Cephalon (P.M.O. no. 67864b) with grooved cheeks.
Fig. 5. Cephalon (P.M.O. no. 67864a) with almost smooth cheeks.
Fig. 6. Cephalon (P.M.O. no. 67854a) with faintly grooved cheeks.
Fig. 7. Small pygidium (P.M.O. no. 67864d) with reticulated pleural areas.
Fig. 8. Small pygidium (P.M.O. no. 67854b) with reticulated pleural areas.
Fig. 12. Larval cephalon (P.M.O. no. 67864c) with grooved cheeks.

Agnostus (*Homagnostus*) *obesus* BELT 1867 – p. 182

2aβ. The alum shale quarry, Gamlebyen, Oslo. Old collection.

Fig. 13. Cephalon (P.M.O. no. 61458a).
Fig. 14. Pygidium (P.M.O. no. 61458b).

Trolmen, Västergötland, Sweden (for comparison). Coll.: G. Henningsmoen, 1956. Zone of *Olenus*, subzone of *Olenus gibbosus*.

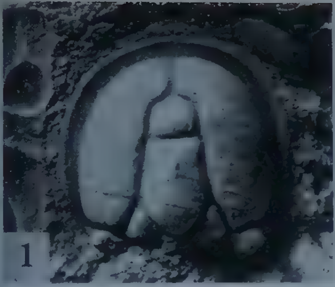
Fig. 15. Cephalon (P.M.O. no. A 27157).
Fig. 16. Pygidium (P.M.O. no. A 27158).

Glyptagnostus reticulatus reticulatus ANGELIN 1851 – p. 184

2aβ. Ringsaker. Coll. Th. Münster, 1879.

Fig. 17. Pygidium (P.M.O. no. 30214). Figured by BRÖGGER, 1882, pl. I, fig. 11b.

PLATE 5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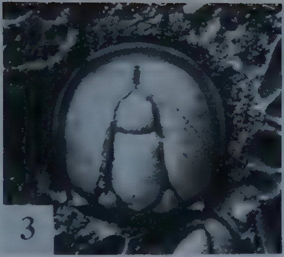
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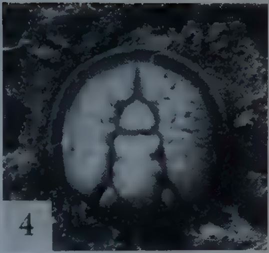
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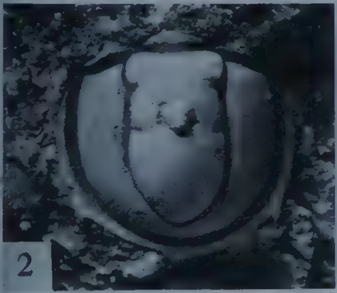
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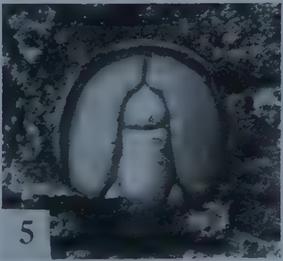
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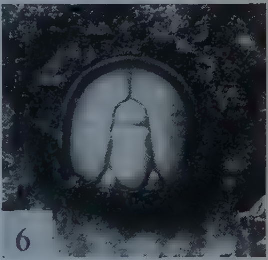
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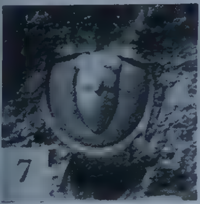
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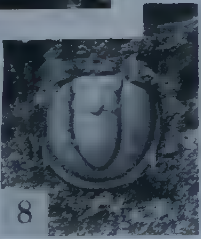
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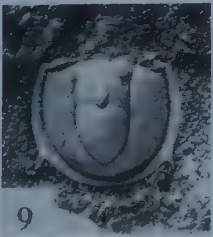
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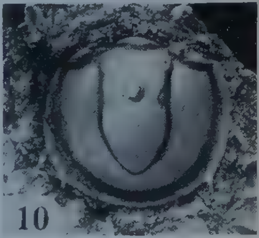
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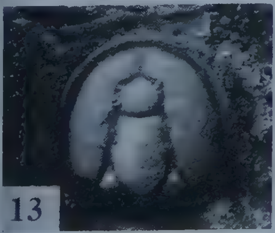
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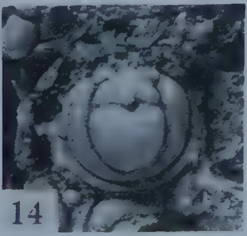
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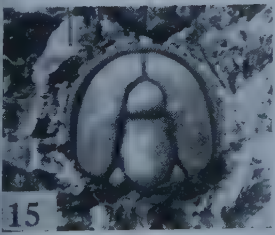
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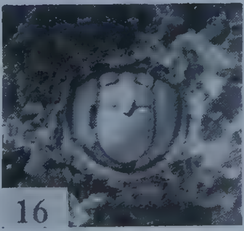
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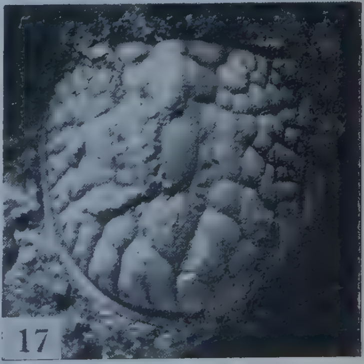
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PLATE 6

The photographs are not retouched. The specimens were whitened with ammonium chloride.

Niobella? primaeva WESTERGÅRD 1909 – p. 185

2dε. Røne shale quarry, Løyten, Nes-Hamar. Coll.: S Skjeseth, 1954.
Fig. 1. x 3.6 Pygidium (P.M.O. no. 69312).

2dε. Beach at Nærsnes gård, Røyken, Oslo-Asker. Coll.: G. Henningsmoen and N. Spjeldnæs, 1954.
Fig. 2. x 3.3. Frontal part of cranidium (P.M.O. no. 69319)
Fig. 3. x 3.3 Pygidium. Latex cast of P.M.O. no. 69320.
Fig. 4. x 6.6 Small cranidium. Latex cast of P.M.O. no. 69321.
Fig. 5. x 6.6 Small pygidium (P.M.O. no. 69322).
Fig. 6. x 6.6 Larval pygidium (P.M.O. no. 69323).
Fig. 7. x 6.6 Pleuron (P.M.O. no. 69324) (Light from below).
Fig. 8. x 6.6 Small hypostome (P.M.O. no. 69318a).
Fig. 9. x 6.6 Hypostome (P.M.O. no. 69318b).

PLATE 6

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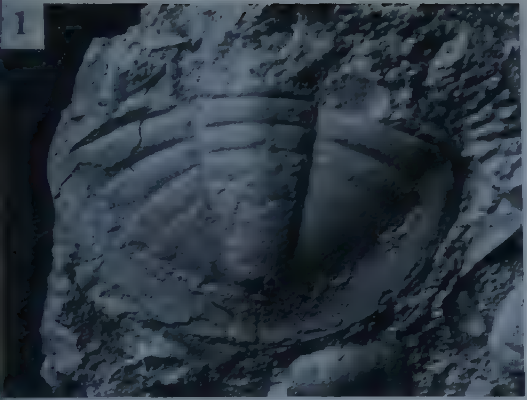

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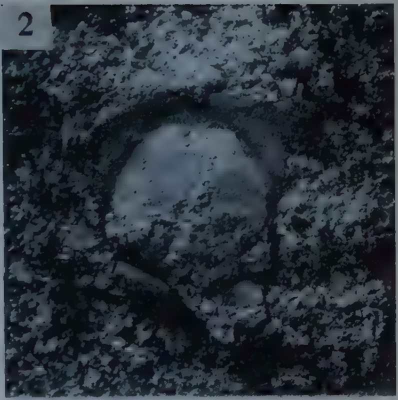

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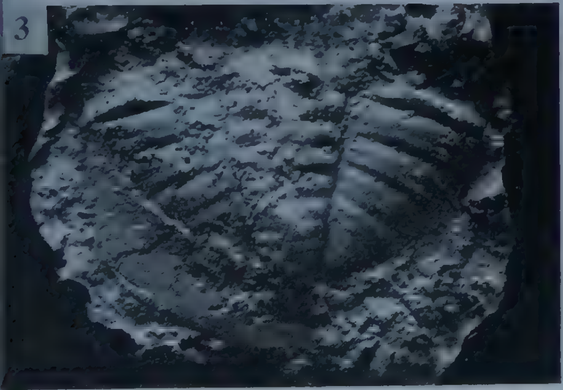

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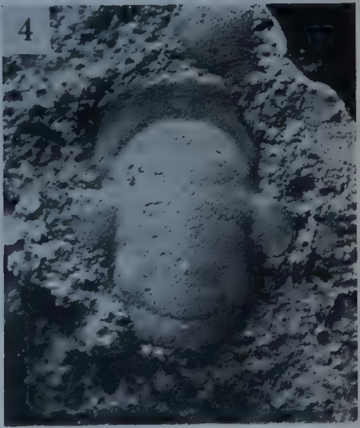

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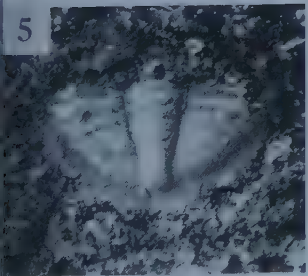

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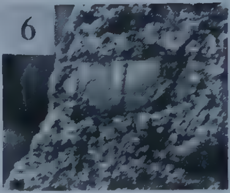

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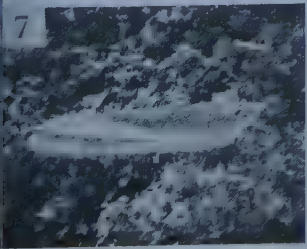

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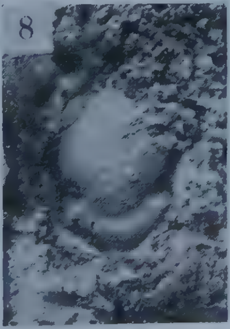

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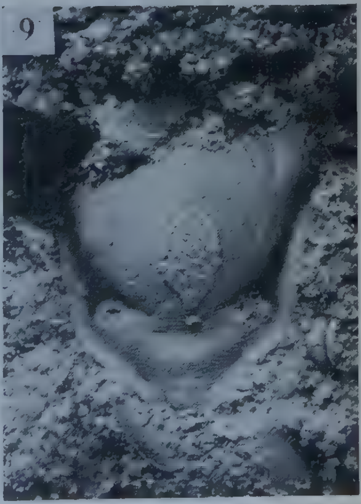

PLATE 7

The photographs are not retouched. The specimens were whitened with ammonium chloride.

Eoorthis? sp. – p. 188

2d*γ*. Beach north of Slemmestad, Røyken, Oslo-Asker. Coll.: T. Strand, 1928.

Fig. 1. x 6.6 P.M.O. no. 29550.

Proceratopyge nathorsti WESTERGÅRD 1922 – p. 186

2a*α*. Mælum, Ringsaker.

Fig. 2. x 6.3 Pygidium (P.M.O. no. 66763). Coll.: S. Skjeseth, 1949.

Fig. 3. x 6.3 Free cheek (P.M.O. no. 30249). Coll.: W. C. Brögger.

Protospongia? sp. – p. 189

2b *spin*. Steinsodden, Ringsaker. Coll.: S. Skjeseth, 1949.

Fig. 4. x 13.2 To the left a spicule seen from the shaft side (P.M.O. no. 69325a). Only the base of the shaft ray is present. To the right another spicule (69325b) seen from the other end. The proximal parts of the four rays are missing, thus revealing where the shaft ray penetrates the rock.

Fig. 5. x 13.2 Spicule (69325c) seen from shaft-less end.

Fig. 6. x 13.2 Spicule (69325d) seen from the shaft side. Only the base of the shaft is preserved.

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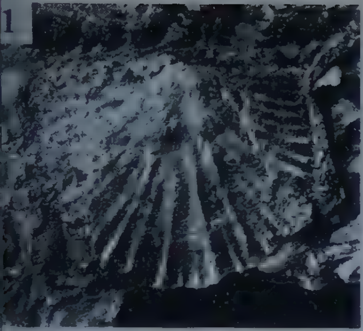

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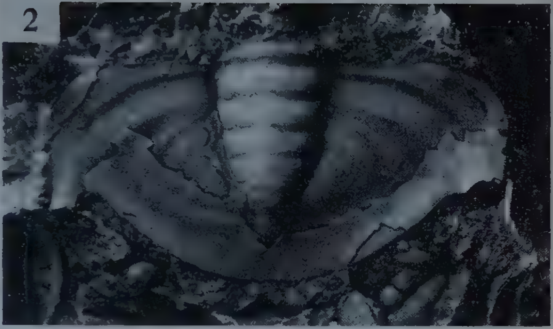

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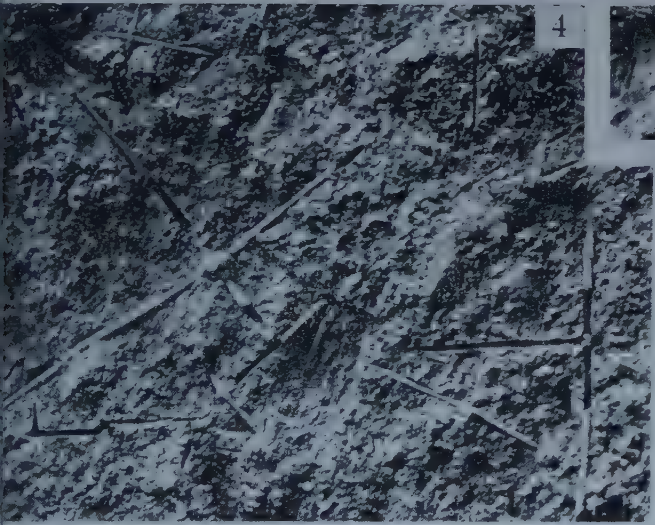

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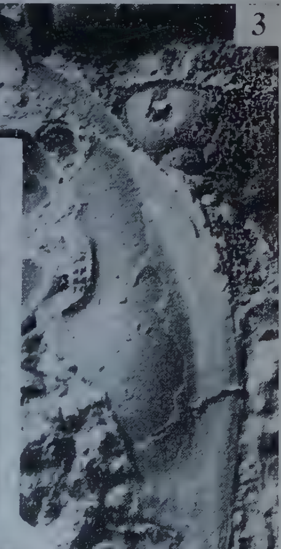

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NORSK GEOLOGISK TIDSSKRIFT 38

A REVIEW OF THE CARBONIFEROUS AND PERMIAN ROCKS OF THE WEST COAST OF VESTSPITSBERGEN

BY
D. L. DINELEY
(University of Exeter)

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Summary and conclusions 215
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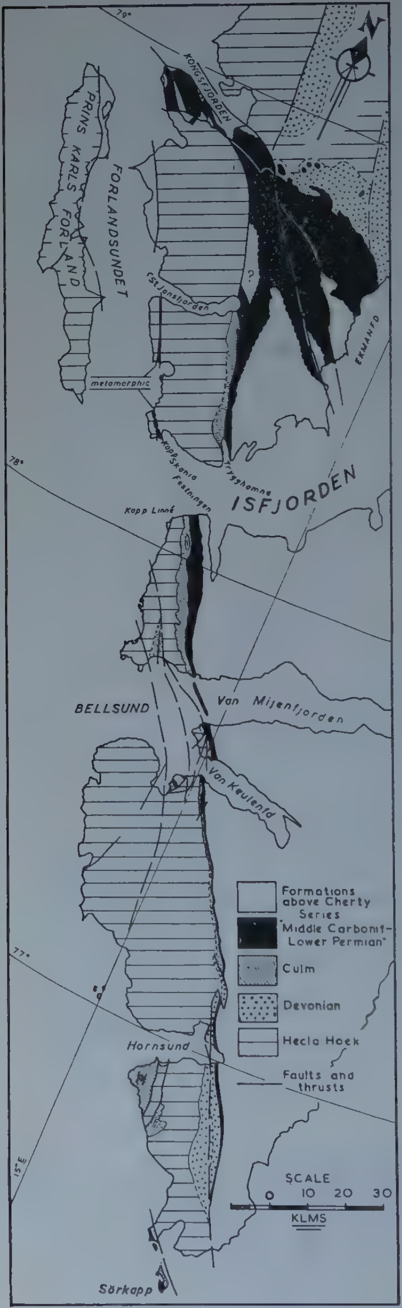
Abstract. The Carboniferous and Permian rocks near the west coast of Vestspitsbergen have been studied only at a few widely separated points, between which considerable variations in character and thickness take place. These variations are probably due to gentle warping of the underlying Devonian and Hecla Hoek basement, coupled locally with fault movement. Various sedimentary and stratigraphical problems are pointed out, including the delimitation of the Culm and the red formations below the Cyathophyllum Limestones. Extensive reworking of early Carboniferous deposits is suggested. The red beds are probably cyclothemic and the presence of marine bands, as at St. Jonsfjorden, should provide useful datum horizons. During Cyathophyllum Limestones times deposition seems to have been more uniform but thickest in the north and at Isfjorden. Variations in the chert sequence appear to be small. The problem of the "Wittenburg facies" above the cherts is mentioned.

Introduction.

GENERAL SETTING

The Carboniferous and Permian rocks in western Vestspitsbergen form a generally very narrow belt running from Kongsfjorden southwards some 300 km to Sørkapp. South of St. Jonsfjorden it is seldom



more than two or three kilometres across and the strata are for the most part steeply inclined to the east, locally becoming overturned. Between the outcrop of the lowest Carboniferous rocks and the west coast lies an area of Hecla Hoek (metamorphic) formations from 10 to 35 km wide. Some Devonian sediments also are present near Hornsund and locally there are faulted outliers of Lower Carboniferous lying some way west of the main outcrop. Between St. Jonsfjorden and Isfjorden Middle or Upper Carboniferous beds have been caught up between thrust faults in the Hecla Hoek (WEISS, 1953; BAKER, FORBES, HOLLAND, 1952).

From Bröggerhalvøya south-eastwards to Ekmanfjorden and central Vestspitsbergen extends a broad outcrop of the Carboniferous and Permian, while an extensive area of the same beds runs across north-eastern Vestspitsbergen to Nordaustlandet.

The present paper reviews the Carboniferous and Permian formations near the west coast and points out some of the stratigraphical and sedimentary problems connected with them.

←

Fig. 1. Sketch map of geology of Western Vestspitsbergen.

PREVIOUS WORK

Some of the earliest systematic investigations into the stratigraphy of the Carboniferous and Permian in western Vestspitsbergen were carried out by A. G. NATHORST (1910) and later by HOEL during the (ISACHSEN) Prince of Monaco's expeditions (HOEL, 1915), but the first major contributions are those of HOLTEDAHL (1911, 1913), who travelled over much of the ground between Kongsfjorden and Bellsund and established the broad stratigraphical divisions.

ORVIN's description (1934) of the geology of the Kongsfjord region gives the first detailed account of the stratigraphy and structure of the Carboniferous on the west coast. The same author in 1936 visited Ahlstrandodden, Reinodden and Hornsund to make a brief examination of the Upper Palaeozoic rocks there. In 1937 he published with HOEL an account of the section west of Festningen on the southern side of Isfjorden, while FREBOLD (1937) described the Upper Carboniferous and Lower Permian stratigraphy and brachiopod and lamellibranch faunas.

In his "Outline of the Geological History of Spitsbergen" (1940) Orvin summarizes the available data and briefly illustrates the lateral variations in the Carboniferous and Permian rocks. He emphasizes the large distances separating the areas in which the succession is known and indicates some of the difficulties of correlation. Details of two further Carboniferous-Permian sections on the west coast are now to hand. The Birmingham University expedition of 1948 gave WEISS (1949) the opportunity to record the succession at Trygghamna on the northern side of Isfjorden, and during a second expedition in 1951 P. A. GARRETT and D. W. GOSSAGE reconnoitred the geology at the head of St. Jonsfjorden. A subsequent joint expedition from Birmingham University and University College, Exeter, permitted Garrett and the present writer to continue that work in 1954.

DIFFICULTIES

Geological work in Vestspitsbergen is often made somewhat difficult by scree, gravels, moraine, snow and ice which may obscure the solid formations. The softer, more fissile rocks are usually covered with a heavy mantle of weathered debris. Harder formations often give rise to dangerous and inaccessible slopes. Continuity of outcrop is frequently broken by the glaciers, many of which undoubtedly lie along zones of unconformity or faults, and critical areas are obscured. The Tertiary earth-movements had great effect and, although ORVIN (1940) has indicated the broad pattern of the folding, thrusting and faulting, the picture is locally much more complicated than may be gathered from the literature. Shale and evaporite horizons have acted as zones of interstratal movement in St. Jonsfjorden, and probably elsewhere as well. These difficulties tend to slow up stratigraphical work but it is nevertheless already apparent that the changes in lithology and sequence from place to place pose real and important problems.

THE "STANDARD" SUCCESSION

It is difficult to draw up a detailed "standard" succession for the Carboniferous and Permian rocks of Vestspitsbergen. The west coast sequence varies greatly from place to place and is in some respects different from that in the central region. However, the following scheme may be adopted as representative for the west coast.

Usually accepted age	*Facies and Formation names*
?Lower Permian – Eotriassic	Rapidly alternating dark brown and buff sandstones and shales.
Upper Carboniferous – Lower Permian	Bedded cherts, siliceous shales, mudstones and limestone. *Erachiopod Cherts*
Upper Carboniferous	Yellow grey, fossiliferous limestones, sometimes silicified or sandy. *Cyathophyllum Limestones*
?Middle Carboniferous	Red sandstones, conglomerates and shales.
Lower Carboniferous	Pale quartzitic sandstones and conglomerates, rare thin black shales and "coals". *Culm.*

THE PROBLEMS

Deposition in Vestspitsbergen during the Carboniferous and Permian periods appears to have been on a fairly stable shelf, which suffered from time to time movement along generally north-striking faults. This resulted in differing successions being laid down between the central and the western areas. (See Gee, Harland, McWhae, 1952; McWhae, 1953). Palaeontological data are meagre and the ages of the various formations are by no means everywhere accurately fixed. Until many more collections have been made the correlation of the different series will largely rest on lithological criteria and this is by no means trustworthy.

For the greater part of the west coast area the outstanding problems are:

1. To determine accurately the limits and boundaries of the various formations and their relationships to one another.
2. To produce a dating based upon detailed palaeontological evidence.
3. To account for lateral changes in lithology and thicknesses, and to determine whether or not they are diachronic.

Coupled whith these are the problems of correlation with central and eastern Vestspitsbergen, other arctic regions, and Europe.

Carboniferous and Permian sections on the West Coast

Knowledge of the Carboniferous and Permian rocks on the west coast is virtually limited to sections exposed where the great fjords cross the Tertiary fold-belt. These are at Kongsfjorden, St. Jonsfjorden, Trygghamna, Festningen, Reinodden and Ahlstrandodden in Bellsund, and at Hornsund, and are briefly described below (Fig. 2). The writer knows no detailed sections recorded south of Hornsund.

(a) KONGSFJORDEN (Orvin, 1934)

At Bröggerhalvøya, on the south side of Kongsfjorden, 125 m or so of Culm rest on both Hecla Hoek and Devonian formations, and consist of light sandstones, conglomerates, thin dark shales and a coal seam. The thin Middle Carboniferous appears to be represented by alternating conglomerates and limestones which are said to form a passage into the (Upper Carboniferous) Cyathophyllum Limestone. The latter includes also dolomites in the lower part, and shales and cherts above. Some of the beds are "ashphaltic". The Lower Spirifer or Cora Limestone of the south is not recorded and some 250 m of Brachiopod Cherts are next present. They include a 40 m glauconitic sandstone which is not found around Isfjorden. Tertiary beds rest unconformably on the Cherts.

(b) ST. JONSFJORDEN (GARRETT AND DINELEY, forthcoming)

The Culm here is presumed to rest directly on Hecla Hoek rocks and it includes two formations. The Trygghamna Formation is at least 200 m thick and consists of pale or cream massive quartzites,

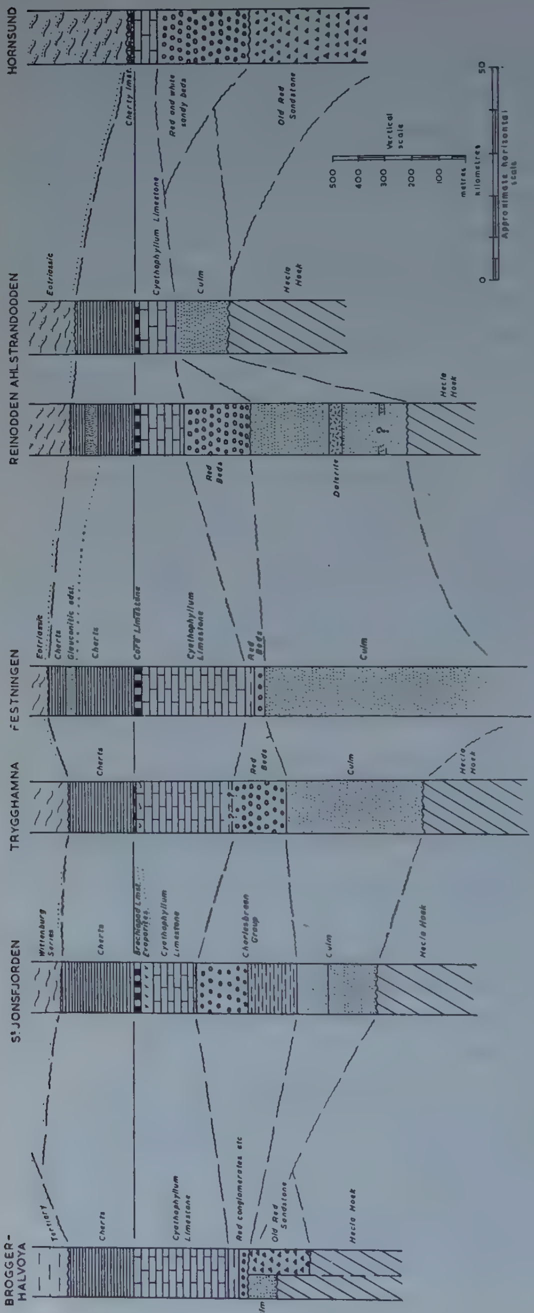


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Fig. 2. Comparative sections in the Carboniferous and later rocks of Western Vestspitsbergen.

conglomerates and rare black shales. It has yielded no fossils beyond plants. The Vegard Sandstone Formation is more thinly bedded pinkish quartzose sandstones and thin shales and forms a passage, some 125 m thick, into the overlying red Charlesbreen Group (Middle Carboniferous). This group also consists of two formations – thick red shale below and massive quartzites and conglomerates above, in all about 440 m. Thin evaporites occur at two levels in the shales. Two distinct marine bands occur in the upper group which appears to be cyclothemic. The "Cyathophyllum Limestones" (220 m) follow with probable unconformity and include remarkable cellular-weathering limestones and thick evaporites immediately below the Brachiopod Limestones. Some 240 m of the Brachiopod Cherts complete the Palaeozoic sequence and are overlain by an immense thickness of thinly bedded dark shales and sandy strata, here called the Wittenburg Series.

(bi) CARBONIFEROUS ROCKS ON FORLANDSUNDET

Mention has been made elsewhere (BAKER, FORBES, HOLLAND, 1952; WEISS, 1953) of the fossiliferous Middle – Upper(?) Carboniferous rocks lying between the Hecla Hoek Formations between St. Jonsfjorden and Trygghamna. The Carboniferous beds are intensely deformed but their original sedimentary characters are often discernible. The grade of metamorphism shown is, so far, not recorded in Carboniferous outcrops elsewhere and in this and certain other respects these Carboniferous rocks resemble the Western Series of the local Hecla Hoek. The latter include "bean-conglomerate" quartzites near Thorkelsenfjellet and at other points to the south, and numerous fine-grained quartzites are inter-bedded with (thinner) green chlorite-grade pelitic rocks. WEISS (1953, p. 280) notes the rapid compositional variation of the rock types in the Western Series and this again bears strong resemblance to that in the upper part of the Culm or, more closely, to that in the Charlesbreen Group. It may be possible that the Western Series of the Hecla Hoek rocks at Forlandsundet is indeed greatly deformed Carboniferous material, but at present this matter can only be one for conjecture. Further discussion is not possible here and further field work is needed to elucidate the problems concerning this strip of deformed Carboniferous strata. South of Kapp Skania no further *highly deformed* Carboniferous wedges are recorded within the main Hecla Hoek outcrop, but their occurrence is not impossible.

(c) TRYGGHAMNA (WEISS, 1949)

The following is based on unpublished work by Weiss, who found the Culm (with a coarse basal conglomerate) resting directly on the Hecla Hoek. It consists of 700–800 m of coarse pale yellow or white quartzitic sandstones and conglomerates. Many of these are strongly cross-bedded and ripple-marked with abundant plant remains preserved as carbonaceous impressions. Black carbonaceous shales occur, some of them containing enough carbon to be described as coals. Red beds like those at St. Jonsfjorden succeed the Culm. A thickness of 125 m is estimated by Weiss but it seems possible that a further 200 m may exist below Trygghamna. Strong evidence of faulting was found in these rocks. Light grey fossiliferous "Cyathophyllum Limestones", estimated to reach 500 m, come next. Traces of cellular-weathering limestones and gypsum were noted. Four to five metres of "Spirifer Limestone" (=Lower Spirifer Limestone, Cora Limestone, Brachiopod Limestones) occur above, followed by some 364 m of cherty beds. The nature and relationships of the strata above the cherts were not investigated.

(d) FESTNINGEN (HOEL and ORVIN, 1937)

The Festningen (Kapp Starostin) coastal section lies on the southern side of Isfjorden, about 20 km south of Trygghamna. Only the upper parts have been described in detail and the lower boundary of the Carboniferous has not been fixed. The Lower Carboniferous is very thick, probably more than 700 m, but it has not been subdivided. HOEL (1925, p. 15) gives the Culm as 980 m thick between Isfjorden and Bellsund, but appears to include all beds below the Cyathophyllum Limestone. The Middle Carboniferous is thin, given as about 60 m including conglomerates, sandstones and shales. It gives way above to 450 m or so of Upper Carboniferous limestones, the top 180 m of which are designated as "Cora Horizont". The exact thickness of the "Cora Limestone" is not made clear, but the "Horizont" caps the thick limestones and is overlain by about 360 m of cherts. Triassic beds lie unconformably upon the cherts.

(e) REINODDEN

Reinodden lies between Recherchefjorden and Van Keulenfjorden on the southern side of Bellsund, 65 km south-south-east of Isfjorden.

The beds are here inverted and greatly faulted. ORVIN's section (1940, pl. II) shows Lower Carboniferous about 700 m thick, the upper part of which is shaly. The Middle Carboniferous is indicated as lying unconformably above and consisting of some 250 m of red and grey conglomerates, sandstone and shales (cf. 1940, p. 25, 200 m). Above the Upper Carboniferous Cyathophyllum Limestone, given as about 140 m, lie 4–5 m of Cora Limestone and 260 m or more of cherty beds. The Triassic unconformably caps the sequence.

(f) AHLSTRANDODDEN

Though the section here is situated only about 7 km east of Reinodden, it is significantly different. Tertiary earth-movements may have reduced the distance originally separating the two sections by 5 km, possibly much more. ORVIN (1940, pl. II) shows 200 m of Lower Carboniferous sandstone, etc., resting on the Hecla Hoek and directly overlain by about 140 m of Cyathophyllum Limestone. The Cora Limestone is present and the cherts reach approximately 260 m when they are overlain by the Triassic.

ORVIN (1940, p. 25) reports that a series equivalent to the Lower Gypsum-Anhydrite Series at Billefjorden is 30 m thick at Bellsund. He does not say what evaporites are present.

(g) HORNSUND

Southwards some 50 km along the strike from Van Keulenfjorden lies the Hornsund section. Here ORVIN (1940, pl. II) records Middle Carboniferous resting directly on Devonian and represented by 450 m or so of alternating greyish white and red conglomerates, sandstones and red shales, followed by grey sandstone and finally limestones and sandstones. No recognition of the Cyathophyllum Limestones or Cora Limestones is made. Cherty limestone, about 12 m thick, is regarded as disconformable Lower Permian and is in turn overlain by the Triassic.

The Sediments

Very few details are available concerning the petrography of the Carboniferous and Permian sediments. Only general terms have been used in describing the composition and sedimentary features of most of

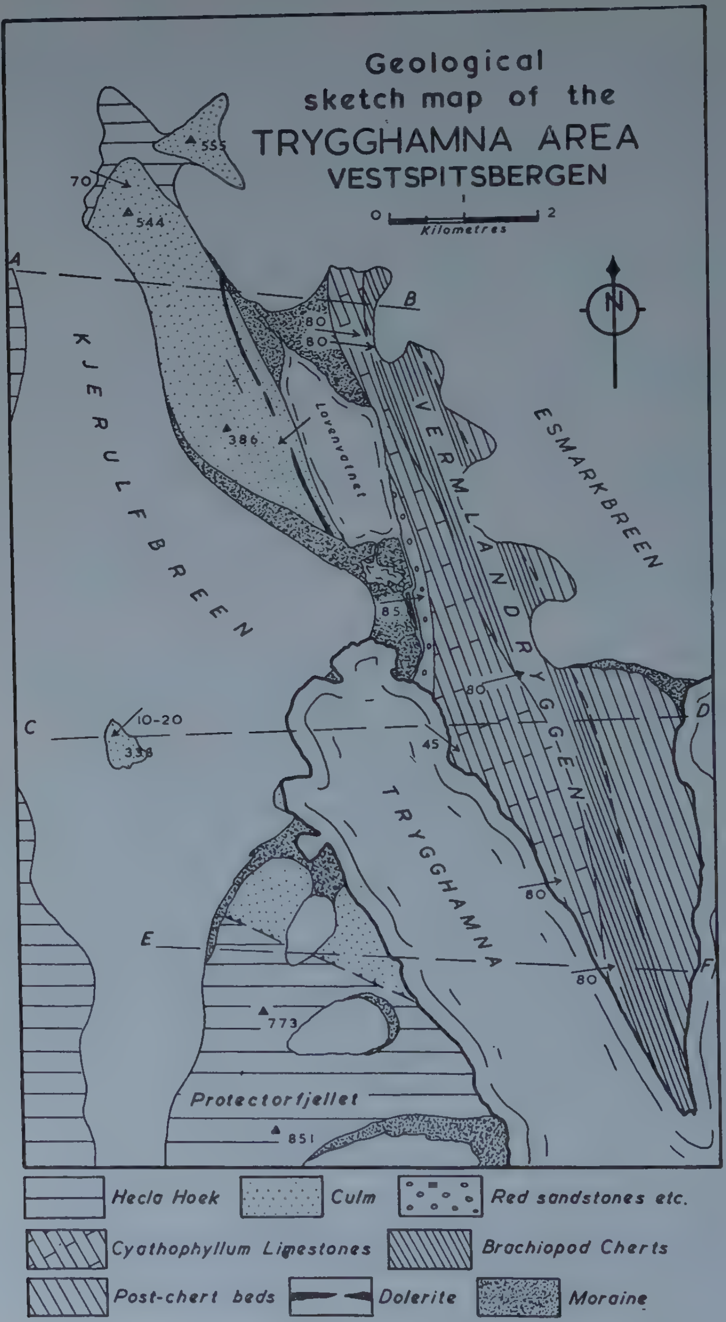

Fig. 3. Geological Sketch map of the Trygghamna area (WEISS).

the various deposits. The need for accurate sedimentological work on these formations is obvious and they offer excellent opportunity for such study. Nevertheless, the known lithological characteres and associations of the beds suggest very strongly deposition on a shelf, stable, though locally affected by small but rapid vertical movements. As yet the nature of these movements and their effects on sedimentation are not properly understood. It is clear that the shelf was very extensive and several authors appear to include within it Bjørnøya, Novaya Zemlya and Greenland and the fringes of Siberia. However correct this may be, it would seem that at least during Lower and Middle Carboniferous times comparatively local tectonic conditions were of major importance to the sedimentation. The following discussion of the sediments is based on the existing literature and the author's field observations. No doubt it is incomplete and inaccurate in several respects, but its purpose is to call attention to the existing problems.

In attempting to interpolate between the known sections, it should be remembered that the length of the outcrop under discussion is some 300 km while the maximum thickness encountered is about 1.6 km. The sediments are thus in the form of very thin sheets and the continuity of the facies and even complete individual formations is likely to have been broken by relatively slight tectonic activity.

Prior to the deposition of the Culm, strong earth-movements affected the Hecla Hoek and Devonian and the central north-south fault zone of Vestspitsbergen was produced. To the west of this lies the region which subsequently acted as a relatively stable though slowly sinking block. Earth-movements at later dates have tended to produce structures with a strong north-south component, controlled by tectonic features in the pre-Carboniferous basement.

a. LOWER CARBONIFEROUS *CULM*

The dominant rock type in the Culm is quartzose or quartzitic sandstone and conglomerate, pale grey or yellowish in colour. The basal conglomerates, however, include quantities of well rounded Hecla Hoek and Devonian fragments. Higher, these materials are very subordinate to vein quartz pebbles. (A few beds are pink- or yellow-stained by iron compounds). There is little felspar or mica and a generally orthoquartzitic character prevails. To the conglomerates, which are often of well rounded and apparently uniform vein quartz pebbles, the term "bean-conglomerate" may often aptly be given.

The bedding planes are usually sharply defined and the individual beds extensive. Cross-bedding is probably general and many beds are current ripple-marked. Carbonized plant impressions, often very large, are abundant in some of the quartzites and may show a rough alignment of the largest fragments. These fossils represent typical Lower Carboniferous pteridosperms, filicales, lycopods, etc., and have been extensively studied by Nathorst (1920). Animal life seems to be almost completely unrepresented.

These features point to shallow water deposition and littoral conditions have been suggested. NATHORST (1910) regarded the Culm as of freshwater and brackish water origin, (swamp and estuarine). The absence of alkalies and iron compounds has been ascribed to humic action. Carbonaceous strata, however, appear to form only an extremely small fraction of the Culm, and the leaching of alkalies, etc., by a local flora is not regarded as a very satisfactory hypothesis. Certainly, humic action may have assisted but it may be pointed out that unstable and soluble minerals are usually rare in orthoquartzitic sediments and this reflects on the physical rather than the biological aspect of their accumulation. In any case, it seems reasonable to believe that much of the Culm sediment was derived from the denudation of Hecla Hoek formations, which locally include enormous quartzites, and from the Old Sandstone sediments which similarly contained much available quartz. The basal Culm unconformity is probably one produced by slow thorough planation, during which the re-working of sediments would be effected perhaps several times.

Black carbonaceous shales and "coals" are found in the lower part of the Culm but they are often streaky and lenticular. The "coal" is invariably very ashy. Except at Pyramiden in central Vestspitsbergen, coal seams in the accepted sense are apparently lacking,and with them the true seat-earths or underclays. At Pyramiden the thickest coal seam reaches about 7 m, but this includes more than 1 m of interleaved shales. The carbonaceous material seems often thus to be cannel-like, allochthonous rather than autochthonous. The relationship of the thicker "coals" to the enclosing sediments in the Spitsbergen Culm would appear to remain a problem of considerable importance.

Finally, the use of the term "Culm" calls for comment. It is now

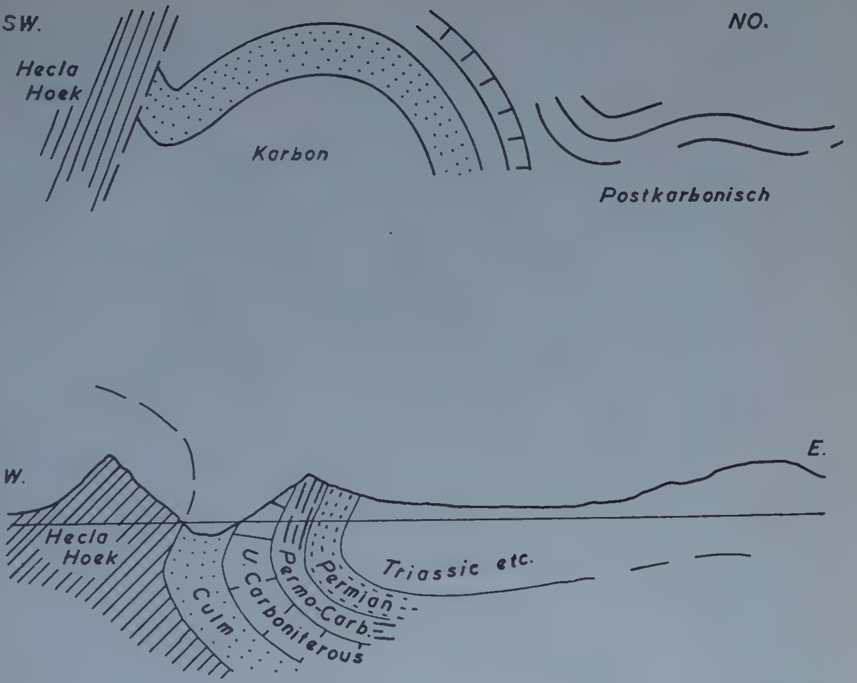

Fig. 4. The structure of the Trygghamna area according to (a) HOLTEDAHL and (b) ORVIN.

so firmly established that the substitution of another would cause confusion. Plant remains and even "coals" ("culm"), it is true, are locally found, but they may be thought of generally as drifted material. Yet it should be remembered that the Lower Carboniferous beds of Vestspitsbergen seem to bear little or no affinity to the Culm Measures of S. W. England nor to the Kulm of Germany, both of which are now regarded as fairly deep water accumulations with greywackés typically developed.

b. ?MIDDLE CARBONIFEROUS *RED BEDS*

While deposition was continuous from Culm times into the Middle Carboniferous in western Vestspitsbergen, it was interrupted by earth-movements and elevation in the central and eastern areas. Movements along the faults which had been initiated during Upper Devonian times were responsible for this. Erosion was active in the Ekmanfjorden region and apparently also at Hornsund, both areas where these faults are well in evidence. In the areas of continued deposition the movements were accompanied by the facies change from Culm to red beds. As might be expected, the thickness and character of the red beds varies greatly from one place to another (see comparative section, fig. 2). In the Billefjord area the Culm facies appears perhaps to have persisted into Middle Carboniferous times (see GEE, HARLAND, McWHAE, 1952). ORVIN (1940, p. 24) stresses that the age of the conglomerates below the Middle and Upper Carboniferous limestones may vary, though they have not as yet been very extensively studied.

The writer has been particularly interested in the red beds (Charlesbreen Group) at St. Jonsfjorden where they are well developed and rest conformably as far as can be seen – on the pink-white Vegard Sandstone Formation. The Charlesbreen Group is undoubtedly the equivalent of the red beds found elsewhere and it may subsequently be shown that the features described below are widespread. At the base of the shales in the lower part of the red beds thin evaporites and limestones are present, and gypsum is found again higher up. For some little way below the lowest massive (Tårnkanten) sandstone the shales are black and contain a bone-bed horizon. The massive sandstones are quartzose, quartzitic or calcareous. Felspar is present in very small quantity in one or two beds but is otherwise very rare. A study of this and the few other minerals besides quartz would be of great interest. Cross-bedding is usual and sometimes it is peculiarly contorted or disturbed in its upper part, suggesting flow-casting. Current and oscillation ripplemarks, erosion surfaces and other sedimentary features indicate extreme shallowness of deposition. Dessication cracks affect the thin shales between the coarser beds. The undersides of the sandstones and conglomerates are usually very sharply defined, but the beds often grade upwards into finer sediments.

The conglomerates deserve special mention. They often include pebbles of vein quartz, but may frequently contain large quantities of clay pellets and calcareous and ironstone nodules or flakes of limestone, perhaps derived by contemporaneous erosion from the red shales and marls. (Calcareous nodules appear in many of the clay-grade red sediments.) Mixed with this material may be rolled fossils. Thin limestone bands have often been desiccated into small curled plates before being incorporated within the overlying sandstone so that the latter seems to possess a basal edgewise or sharpstone conglomerate.

Fossils are sporadically distributed, are often silicified or even jasperised and appear to have been rolled and worn. Marine forms include productid, spiriferid and schizophorid brachiopods, isolated crinoid ossicles and broken corals. Rare lingulae are present at some horizons and fragmentary plant remains occur locally.

At St. Jonsfjorden fossils are also present in two distinct marine bands – black shales with grey argillaceous limestone. The fauna of each band is abudant and distinctive and should prove to be great value in correlation. Spiriferid and stropheodontid brachiopods are by far the most numerous fossils, but other brachiopods, small pelecypods and corals occur, and a single trilobite fragment has been found. These marine bands are obviously most important marker horizons and should be sought wherever the red bed facies is developed. It is suggested that the red Tårnkanten Sandstones of St. Jonsfjorden are cyclothemic, the marine bands indicating sudden depression and transgression followed by long phases of deltaic-littoral accumulation.

A sharp break break between these beds and the Cyathophyllum Limestones is postulated at St. Jonsfjorden, but elsewhere a continuous passage seems to be the case. That the red beds mark a phase of semi-continental and littoral accumulation is generally accepted. Much of the material appears to be reworked and the Culm desposits of central Vestspitsbergen may have locally provided the sediment. Where the exposures are good, it should be a matter of no difficulty to collect evidence showing the principal direction of the streams depositing the sandstones and conglomerates. In eastern Vestspitsbergen Hecla Hoek detritus may have been incorporated, but on the west coast there seems to be little of this material in evidence. The Lower Gypsiferous Series of Billefjorden appears to be confined virtually to the tectonic basin there, overlapping on to the west coast area only at St. Jonsfjorden as far as is known. The Passage Beds which follow the Lower Gypsiferous Series give way upwards to the Cyathophyllum Limestones.

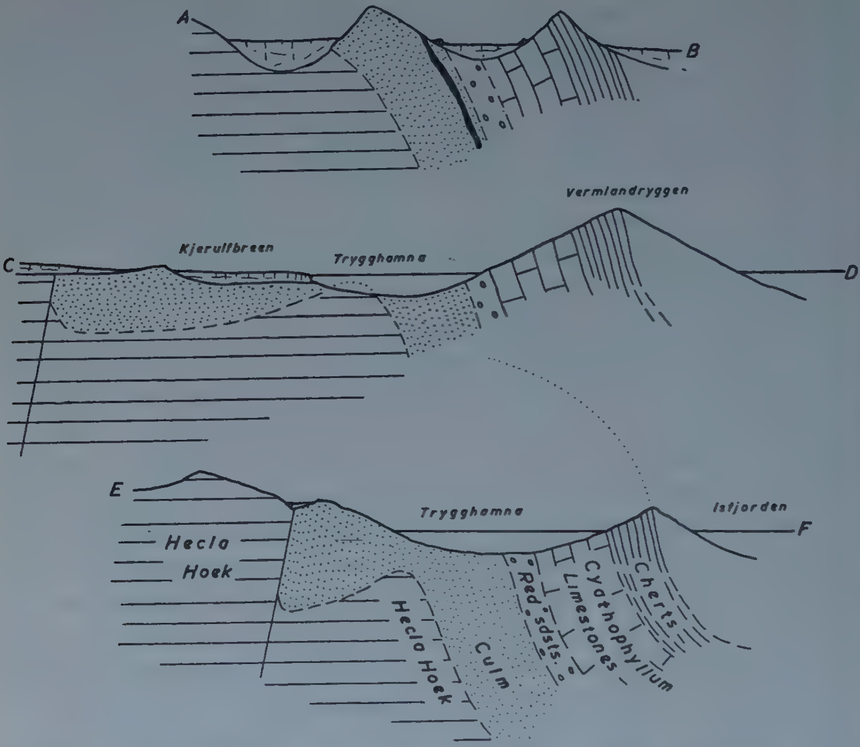

Fig. 5. Sections across the Trygghamna area: present interpretation.

c. UPPER CARBONIFEROUS *CYATHOPHYLLUM LIMESTONES*

These consist of thinly to massively bedded, fairly pure grey limestones often porcellanous, interleaved with grey shale and silicified. Locally they are fossiliferous with large corals in the growth position. Some beds may have a large (fusulinid) microfauna and crinoid stems and fronds are locally abundant. Bituminous matter is common. Drusy cavities and stylolites are sometimes present. A few sandy beds show the transition from the red beds below.

In the St. Jonsfjord – Trygghamna region a cellular-weathering facies is developed. It appears to be an epigenetic feature associated with the presence of evaporites, and is not recorded elsewhere on the west coast. An investigation of this peculiar facies is at present under way.

The evaporites themselves are similarly geographically restricted and may well be in direct continuity with the Upper Gysiferous Series of central Vestspitsbergen. They consist of white and dark "papery" shales, thin argillaceous limestones and masses of gypsum-anhydrite. (Salt is not recorded.) Their original thickness is difficult to assess as they have flowed during the Tertiary earth-movements. Deposition was probably under a shallow lagoonal environment, but we have no knowledge of the boundary conditions.

d. *"BRACHIOPOD LIMESTONE"*

Though only a small unit, this facies deserves special consideration. At the base of the cherty beds a thin yellow-weathering, often silicified limestone, is often present. It has been variously termed Lower Spirifer Limestone, Cora Limestone, Limestone "A" (GEE, HARLAND, McWHAE, 1952) and Brachiopod Limestone. Lithologically it is very like the underlying Cyathophyllum Limestones, upon which it rests with a sharp conformable junction, but it is usually crowded with spiriferids, productids and other thick-shelled heavy brachiopods. Conodonts have been found at Trygghamna and the limestone also includes fragmental bryozoans. In St. Jonsfjorden it is associated with a thin yellow-grey finely laminated silty limestone, the laminae of which are often intensely contorted. Nathorst found the Cora Limestone to include sandy beds and water worn fossils, and has suggested that it is typically of shallow-water type, formed under brackish conditions. The laminated limestone suggests a shallow lagoonal environment, but in St. Jonsfjorden there is no evidence suggesting brackish water deposition of the very fossiliferous beds. Nevertheless, these limestones are usually regarded as marking the transgression which occurred towards the end of Carboniferous times.

e. UPPER CARBONIFEROUS – LOWER PERMIAN *BRACHIOPOD CHERTS*

The distinctive chert formation consists of siliceous shales and siltstones, silicified mudstones and limestones, massive, thin and rybbly cherts. The colour is generally dark when fresh, but may lighten on weathering. Fossils are principally confined to the shales and limestones and include large sturdy brachiopods, molluscs, blastoids and bryozoans (FREBOLD, 1937). Some beds contain very large numbers of siliceous sponges. It has always been assumed that the chert beds are primary and that the silicification of the shales and limestones took place very shortly after deposition, possibly in the interval preceding the deposition of the Eotriassic strata. The cherts appear everywhere to be overlain by unconformable later beds, but the exact dating of the period of pre-Trias uplift and erosion remains open to question (DINELEY & GARRETT, forthcoming).

The depositing sea is thought to have been "not more than 300 m in depth, and it must have been connected with the sea at East Greenland and the Ural" (ORVIN, 1940), where similar formations occur. A bed of glanconitic sandstone in the cherts at Kongsfjorden indicates a warm shallow sea. Apart from this bed, detrital material is at a minimum. The source areas of the sediment must have been reduced almost to base level and large areas of quartzitic rocks may have been exposed, providing the necessary silica.

f. LOWER PERMIAN – TRIASSIC *"WITTENBURG FACIES"*

Doubt can be thrown upon the generally accepted Eotriassic age of the beds following the cherts at St. Jonsfjorden (DINELEY & GARRETT, forthcoming), but, leaving aside the problem of their age, the beds above the cherts there appear to be essentially similar to those elsewhere in much of western Vestspitsbergen. For convenience their facies may be named after Wittenburgfjella at the head of St. Jonsfjorden. The sequence consists of rapidly alternating and generally thin-bedded silty brown micaceous shales, sandstones often with basal pellet layers, and quartzites. The coarser strata are strongly cross-bedded and ripple-bedded. Micro-ripples are common in the finer beds. There is a great variety of surficial markings, including desiccation marks and "load-cast" and morphologically similar structures, tracks and trails, and immense numbers of "fucoids". Fossils are unevenly distributed; some of the sandstones and siltstones contain numerous nektonic pelecypods. There are occasional silicified limestones crowded with pelecypod and gasteropod remains which have been current segregated into cross-bedded lenticles. A few of the pellet beds contain poorly preserved fish scales and bones.

The sedimentary features and fossils suggest comparatively rapid accummulation in shallow water – perhaps even tidal, with a low-lying but prolific area of sediment supply. The uplift following the deposition of the cherts was obviously not violent, being sufficient to give little angular discordance between cherts and "Wittenburg facies". True continental conditions prevailed at no great distance and the Mesozoic epeiric sedimentation had commenced.

Summary and conclusions

Carboniferous and Permian times saw the deposition of thin sheets of sediment over the greater part of Vestspitsbergen. Some formations are, however, apparently confined to central Vestspitsbergen or are perhaps represented on the west coast by a slightly different facies. It seems that near-continental conditions prevailed during Lower and Middle Carboniferous times, following a period of active erosion. Subsequent deposition was essentially in shallow water and punctuated by periods of local uplift or non-deposition. The eastern boundary of the west coast region may have been defined by faults, initiated in Upper Devonian times and perhaps later moving below a thin sedimentary cover. Tilting and differential movement of fault blocks in the Hecla Hoek basement may have taken place from time to time. Small vertical movements would have had considerable effect on a region in which deposition was very shallow and the source area low-lying. During Middle Carboniferous times the reworking of Lower Carboniferous and Devonian sediments was probably widespread, and the climate hot, perhaps arid. Detrital supply was at a minimum during Upper Carboniferous and Lower Permian times, with evaporites, limestones, cherts and fine shales being deposited. Tectonic activity seems to have been nil.

The principal and obvious problem to be solved is that of the red beds below the Cyathophyllum Limestones. Clearly from place to place they vary in character, thickness and relationships to the limestones. Where there is unbroken continuity from the Culm white quartzites into the red sandstones and shales it may be a matter of some difficulty to select a suitable boundary between these two groups. Field workers so far have had to choose arbitrary limits which it may not be practicable to apply over larger areas. Palaeontological data are few and generally not easy to use in the field.

Subsidence and accumulation appears to have been more active in the St. Jonsfjorden – Trygghamna and Hornsund areas than elsewhere in the west during middle Carboniferous times. At Hornsund this may have been the development and filling of a local graben, while north of Isfjorden it may have been only a slight northward shift of the marked area of subsidence active during Culm times. Possibly this also was influenced by faults, but gentle warping of the basement seems more likely.

The red formations may prove to be widely cyclothemic, the rhythms being associated with gentle uplift of the source area and sudden brief marine incursions. Unless removed by later erosion the marine bands found at St. Jonsfjorden should be widespread and invaluable in correlating and dating the red bed units.

The Upper Carboniferous limestones deposited at St. Jonsfjorden include evaporites and peculiar breccia-like beds, suggesting a shallow area of restricted circulation, perhaps linked directly with the Billefjord evaporite basin. At Bellsund deposition was also thin, but no peculiar limestone facies is reported there.

In consequence to the above, two principal studies suggest themselves. They are:

1. An investigation of the Middle – Upper Carboniferous beds in the area immediately to the west of Ekmanfjorden where fault tectonics may have influenced sedimentation, and where the succession of central Vestspitsbergen probably changes to that found at Kongsfjorden and at St. Jonsfjorden.

2. An investigation of the detailed stratigraphy and palaeontology of the Middle Carboniferous red beds at many more points along their strike southwards from Kongsfjorden. Explanations must be sought for the variations in thickness and relationships to the underlying beds.

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APPENDIX

The structure of the Trygghamna-Vermlandsryggen area, Isfjorden

BY

L. E. WEISS

The Tertiary earth-movements, which produced such complex structure to both the north and south of Isfjorden, have at Trygghamna given rise to a comparatively simple area. NATHORST (1910) attributed the folding to what he described as the great coastal fault in the west, the fault being drawn at the boundary between the Hecla Hoek and Culm formations. Since Nathorst's day much evidence has been gathered supporting the view that strong pressure from the west was responsible for the Tertiary folding and that the faulting is somewhat younger. Overthrusting of the Hecla Hoek on to Carboniferous rocks occurs to the north and recumbent folds in the Carboniferous, overturning to the east, are known south of St. Jonsfjorden. Nevertheless, the structure at Trygghamna seems to remain comparatively simple.

On the western side of Trygghamna the Carboniferous rocks are bounded by a strong fault below Protektoraksla. There the Culm dips fairly steeply to the west, but becomes suddenly vertical and a crush breccia is developed adjacent to the Hecla Hoek rocks.

Vermlandryggen is a strike ridge, rising to about 550 m. On its crest the outcropping rocks are the cherts. The dip is generally very steep to the east, but locally it may be at high angles to the west. At the southern end of the ridge it is nearly vertical, northwards it rarely falls below 80°.

ORVIN's interpretation of the structure of the Trygghamna area is illustrated in a section (1934, p. 80, fig. 30, AB. This paper, fig. 4b). He regarded the Culm-Hecla Hoek junction as non-faulted and the succession to the east inverted. The dips observed on Vermlandryggen and Lovenryggen are, however, eastwards or vertical; nowhere were dips of 50 degrees to the west found. The presence of Culm dipping at low angles westwards on the nunatak and below the snout of

Kjerulfbreen is difficult to explain on ORVIN'S section. It is equally difficult to account for the unconformable junction of the Culm and Hecla Hoek on Lovenryggen, dipping at 70–80 degrees to the east. The interpretation adopted here notes an uninverted sequence on Vermlandryggen and the existence of the fault. This is in agreement with HOLTEDAHL'S account (1913) as can be seen by comparing figure 5 with HOLTEDAHL'S sketch-section.

The difference in strike of the Carboniferous strata on opposite sides of Trygghamna was noted by Holtedahl, but it is not possible to say if this is due to the effects of the fault, deflecting the strike of the Culm on the western side of the fjord or whether a major fault running along the centre of Trygghamna explains this feature.

In view of the more complicated structure some kilometres to the north, e. g. just south of St. Jonsfjorden, it may be asked why the folding at Trygghamna is so open. No doubt several factors are responsible. Trygghamna is situated on the flank of the great southeasterly pitching Tertiary syncline which occupies most of southern Vestspitsbergen, whereas St. Jonsfjorden is nearer to the closure of this syncline. Minor structural influence may be exerted by the variation in the Carboniferous column from place to place with consequent changes in the competency of the beds, and by the varying weight of this column on the Hecla Hoek foundation below.

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ON THE DISTRIBUTION OF STRONTIUM AND BARIUM IN THE ERUPTIVE ROCKS OF THE OSLO REGION

BY

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Abstract. Determinations of the contents of Sr and Ba in a number of specimens of the principal eruptive rock types of the Oslo Region have been made by a semi-quantitative spectrochemical method. The general trends of the resulting figures are in support of the geologically observed age relations within the rock series, all the rocks of monzonitic and similar compositions being comparatively rich in Sr and Ba, and the younger rocks successively poorer. Very striking is the difference between the series biotite nordmarkite – biotite granite on the one hand, and aegirite nordmarkite -- ekerite on the other. In the former series Sr and Ba are still moderately abundant, while in the latter they tend to disappear completely.

The absolute concentrations of Sr and Ba in granites, as well as their coefficients of distribution between the feldspar phases of these rocks, seem to be rather insensitive to variations in the temperature of crystallisation.

It is known that many of the eruptive rocks of the Oslo Region are comparatively rich in Sr and Ba. On the other hand it has been shown recently (1) that a sample of ekerite was extremely poor in Sr. In the course of a survey of various Norwegian rocks as to their contents of Sr and Ba I have collected a considerable material of determinations on Oslo rocks.

Analytical procedure.

The determinations were made by means of a "Hilger Large" quartz spectrograph, using Kodak P-25 plates. The powdered samples were packed into cavities in carbon cathodes of standardized shape and dimensions; the cavity was 1.5 mm in diameter and 4 mm deep, and was always filled completely with the pure substance. The arcing was done at 250 V and about 5 A. Exposure time 2½ minutes. This was found to give fairly consistent results. The arc image was formed on the prism, and a rotating stepped sector employed. The spectral lines used were Sr 4607 and Ba 4554. The stepped lines were compared visually with corresponding ones in spectrograms of standard mixtures containing SrO and BaO in the following concentrations: 30000, 10000, 3000, 1000, 300, 100, 30, 10 parts per million. It was found necessary to prepare two sets of these mixtures, one for comparison with alkali feldspars and one for comparison with plagioclases; the base substances in these were microcline perthite (amazonite) and albite respectively, both of course carefully selected among specimens particularly poor in Sr and Ba. Actually the amazonite contains about 30 p.p.m. SrO and below 10 p.p.m. BaO, and the albite still lower percentages. The intensities of the Ba lines agree fairly well in the spectrograms of the two sets; however, those of the Sr lines differ considerably, especially at low concentrations. At 1% concentration the Sr line is about equally strong in both kinds of spectrograms, but at lower concentrations it grows successively weaker in the albite mixture spectrograms as compared with the amazonite mixture spectrograms. Obviously abundant K in the arc is able to enhance the intensity of the Sr line considerably at low Sr concentrations. In a number of cases, especially in many Oslo rocks, it has not been possible to obtain separate samples of alkali feldspar and plagioclase for arcing. However, in most such cases the concentrations of Sr and Ba are so high that the intensity differences between the spectrograms of the K-rich and the K-poor substances are negligible.

It is obvious that the procedure described will not give a very high degree of accuracy. But the accuracy obtained is sufficient to show characteristic differences between the various rock types.

Mr. Jens Hysingjord, cand.mag., has prepared all the samples and standard mixtures, and taken all the spectrograms.

Results of spectrochemical analysis, and discussion.

As far as possible the Sr and Ba determinations were carried out on pure feldspar samples. Thus the resulting figures apply to the feldspar components of the rocks. In a number of cases the rocks were so

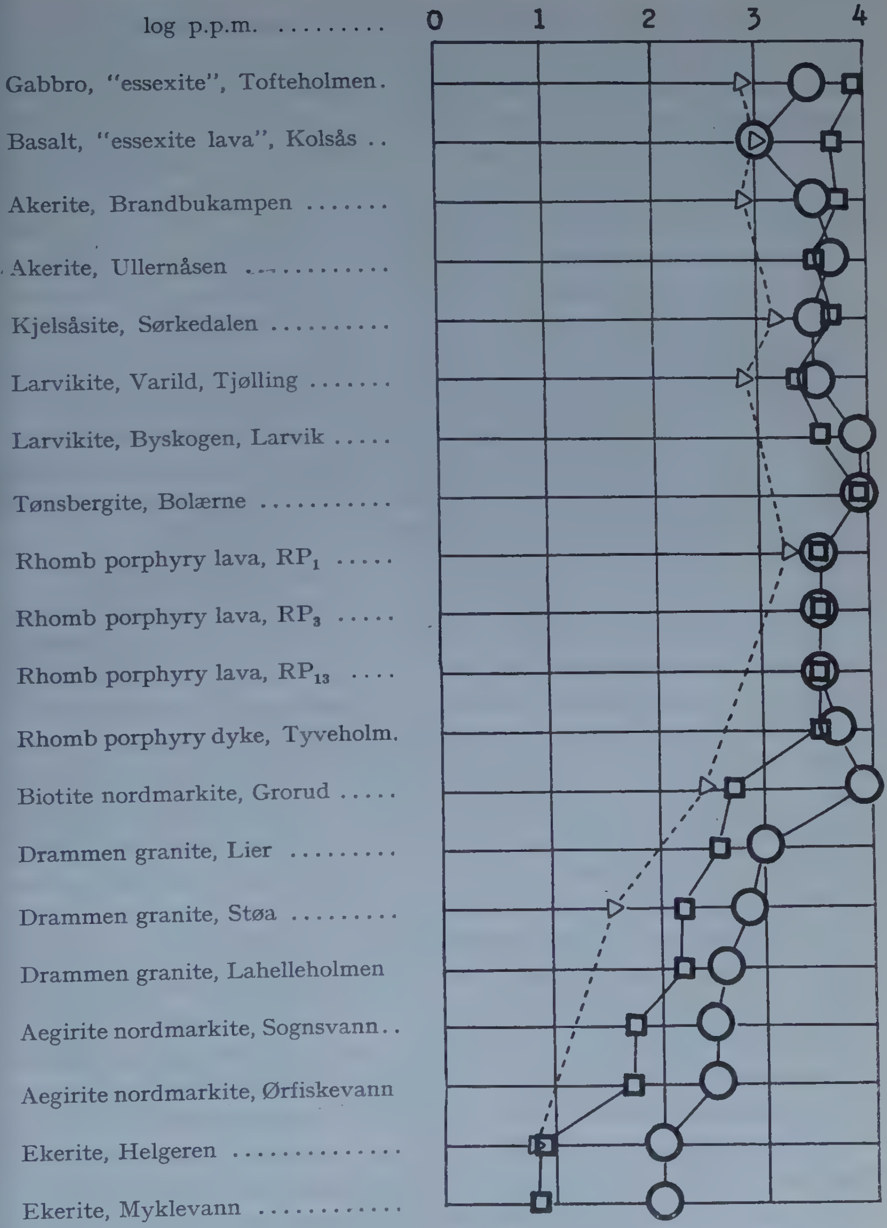
log p.p.m. ....
0
1
2
3
4
Gabbro, "essexite", Tofteholmen.
Basalt, "essexite lava", Kolsås ..
Akerite, Brandbukampen ....
Akerite, Ullernåsen ....
Kjelsåsite, Sørkedalen ....
Larvikite, Varild, Tjølling ....
Larvikite, Byskogen, Larvik .....
Tønsbergite, Bolærne ....
Rhomb porphyry lava, RP₁ .....
Rhomb porphyry lava, RP₃ .....
Rhomb porphyry lava, RP₁₃ ....
Rhomb porphyry dyke, Tyveholm.
Biotite nordmarkite, Grorud .....
Drammen granite, Lier ....
Drammen granite, Støa ....
Drammen granite, Lahelleholmen
Aegirite nordmarkite, Sognsvann..
Aegirite nordmarkite, Ørfiskevann
Ekerite, Helgeren ....
Ekerite, Myklevann ....

Fig. 1.

fine grained that we did not succeed in getting satisfactory feldspar samples, and had to use bulk samples. As feldspar is by far the most abundant constituent of the majority of the examined rocks, this is generally of little consequence. But in the case of the very dark basalts the observed concentrations have been corrected so as to give approximately the concentrations in the feldspars; this could be done fairly safely, as it was shown that the dark minerals of basalts contain much less Ba and Sr than the feldspars. Fig. 1 shows the main results of the Sr and Ba determinations in the feldspars of Oslo rocks. The scale of concentrations is in units of *log parts per million*. Circles represent BaO and squares SrO. All fairly reliable determinations have been included. But a number of other determinations, which I consider less reliable, have been made. These include observations on "essexites" from Brandberget, Dignes, Trasop, Randviksholmen, the "essexite lavas" E_1, E 10 B, E 13 A, akerites from Midtstuen and Ullernåsen, larvikite from Tuft, lardalite from Farris, nearly the whole series of rhomb porphyry lavas RP_1 to RP_{13}, and several other rhomb porphyries, a number of nordmarkites from Sognsvann, Årvoll, Grorud, and others. Although I have not quoted the results from these somewhat inferior spectograms I would add that they are all in support of the general picture shown in Fig. 1. The Sr and Ba contents of the examined specimen of lardalite are similar to those of the larvikites. For comparison we have taken spectograms of basalts from Table Mt, Colorado and from Spitsbergen. Their contents of Sr and Ba agree fairly well with those of the Oslo basalts. In the same way the "rhomb porphyry" from Moshi in Tanganyika exhibits Sr and Ba contents similar to those of the Oslo rhomb porphyries.

The triangles in Fig. 1 represent the Sr determinations in some Oslo rocks given in the paper by Turekian and Kulp (1). (The localities of the various specimens do not in general agree with those quoted in the figure.) In that paper the concentrations have been given in percentages of Sr; these have been recalculated to percentages of SrO, but really they should still be increased a little to be comparable with the present values, as they are percentages of the total rock substances. Even so the values given by Turekian and Kulp are on the average very considerably lower than the present ones. Since the determinations of Turekian and Kulp are said to be very accurate, my values seem to be on the average much too high. I am not able to explain this discrepancy. Of course my standard mixtures are not exactly like the examined feldspars, as they consist of powdered feldspar and the oxides of Sr and Ba, but I think it is surprising that this should make such a large difference in the intensities of the Sr and Ba lines. I may have to admit that my values are too high. But to the present discussion this is of little consequence, since the general trend of the Sr contents in the rock series agrees very well in both sets of determinations, as is apparent in Fig. 1.

From the data presented it appears immediately that the Sr and Ba contents are high and fairly constant in all the rocks of monzonitic composition, including the lardalite. In these rocks SrO and BaO are about equally abundant, and the concentrations in the feldspars are, according to my determinations, several thousand p.p.m., in some cases even as high as 1%. That Sr and Ba are about equally important in these rocks is not surprising, since Sr replaces mainly Ca and Na, and Ba mainly K, in the feldspar structures. We have tried to prepare pure samples of alkali feldspar and plagioclase from some of the monzonitic rocks, with little success. Thus kryptoperthite crystals and what appeared to be "rhomb feldspars" from a specimen of coarse larvikite yielded practically identical spectrograms; the plagioclase crystals are here intergrown with large quantities of alkali feldspar. In rhomb porphyries, of course the phenocrysts and the ground mass could easily be examined separately, but even here the phenocrysts proved to contain large quantities of alkali feldspar in most cases. Only one of the samples from several examined phenocrysts – taken from the central part of a large phenocryst from RP_3 – proved to consist of fairly pure plagioclase (very weak K lines); it yielded SrO 3.7 and BaO 2.7 (log p.pm.). This demonstrates the coherence of Ca and Sr and of K and Ba in these rocks. The ground mass of the same rock, which contains much alkali feldspar, yielded SrO 3.5 and BaO 3.7 (log p.p.m.).

It is seen from Fig. 1 that in some monzonitic rocks SrO was found to be somewhat in excess of BaO, in others vice versa. Although I do not think this observation is of any great importance I would draw attention to the relation between larvikite and kjelsåsite. Here the SrO excess is in the more calcic rock, as would be expected. There seems to be a similar difference between the akerite from Brandbukampen and that from Ullernåsen (the original akerite locality). In the gabbroic rocks SrO is, naturally, considerably more abundant than BaO, but the concentrations are more or less on the same level as in the monzonitic rocks. It may be surprising that Ba is so relatively abundant here, but the K content is very considerable in many of the Oslo "essexites".

Passing from larvikites to nordmarkites, there is a very marked drop in the Sr content, a reduction by a factor of about 10 or more. On the other hand it is seen from Fig. 1 that there exist nordmarkites (mica nordmarkites) which are quite as rich in Ba as the monzonitic rocks. This is not surprising, since nordmarkites consist mainly of alkali feldspar. Such Ba-rich nordmarkites might be formed from monzonitic magmas by concentration of the alkali feldspar component of the monzonite. However, it has been necessary to distinguish between two kinds of nordmarkite on the ground of the Sr and Ba contents. The second kind is much poorer in Sr and Ba than the first one, in fact 10 or more times poorer, and the samples so far examined represent aegirite nordmarkites. Also here the Sr content is much lower than the Ba content. In the related ekerites the decrease in the Sr and Ba contents has proceeded still much further. As compared to the monzonites, the ekerites may be more than 1000 times poorer in Sr and 100 times poorer in Ba.

If we assume that a rock series ranging from nordmarkites of the first kind (biotite nordmarkites) to ekerites is formed by magmatic differentiation, this process brings about a gradual change in the composition of the alkali feldspar, here shown by the gradual disappearance of Sr and Ba. A similar change in the contents of Sr and Ba is observed when normal granites (outside the Oslo Region) are compared with their pegmatitic facies. Granite pegmatites will not be discussed in the present paper, but it may be recalled here that their feldspars are usually much poorer in Sr and Ba than those of normal granites. The Ba content of granite pegmatite is very often similar to that quoted for ekerite. The Sr content is usually considerably higher than that of ekerite, but in some cases it appears that the microcline of (Archaean) granite pegmatite was originally nearly devoid of Sr, as in these cases the microcline is very rich in Rb, so that the small amount of Sr observed must be mainly radiogenic. That the amount of radiogenic Sr in ekerite is negligible, is obvious, both because of the

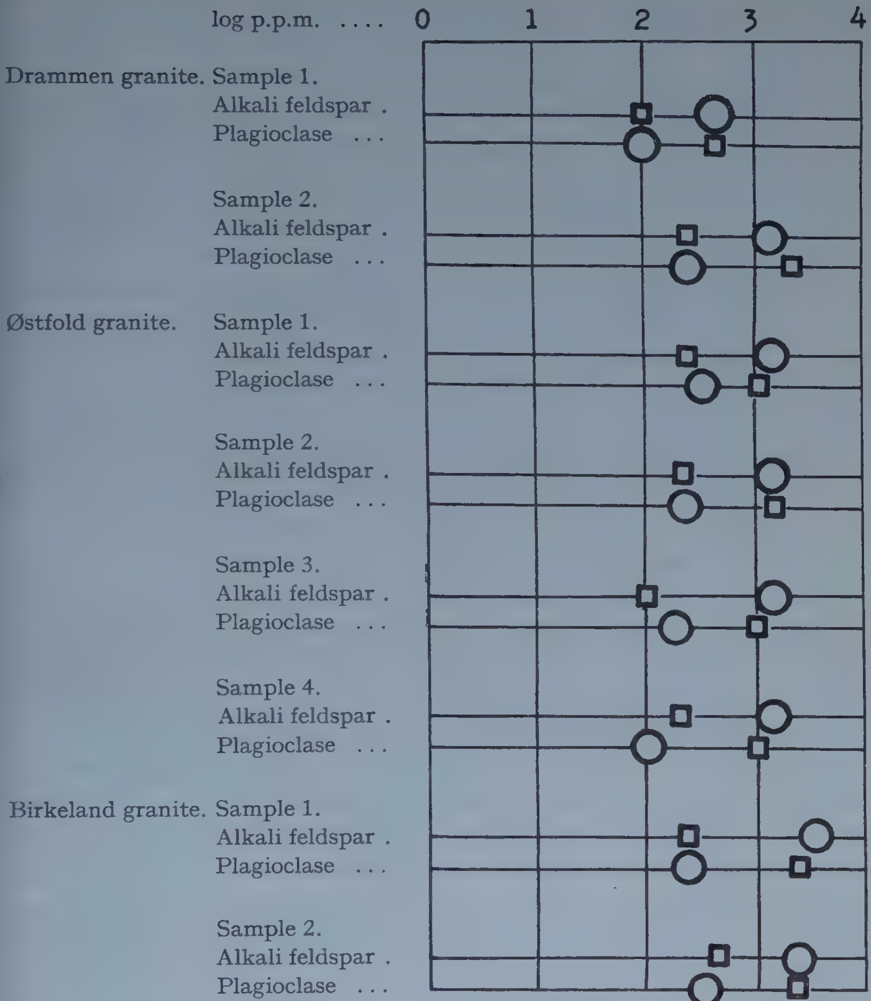

Fig 2.

low Rb content of the rock and because of its relatively low age. It is a well known experience that most of the Sr and Ba in a magma will be consumed by relatively "early" feldspar crystals, so that very "late" feldspar crystals will be relatively poor in these elements.

Therefore it appears that ekerite is younger than nordmarkite in a similar sense that granite pegmatite is younger than a parent granite.

In Fig. 1 the Drammen granite has been placed in between the two types of nordmarkite, for the obvious reason that it is intermediate between these rocks as to the contents of Sr and Ba. Of course I do not suggest that there is a development of aegirite nordmarkite and ekerite from Drammen granite. The trend of the Sr and Ba concentrations is rather in support of the view that the granite as well as the ekerite series branch off from the biotite nordmarkite (2). As far as removal of Sr and Ba is concerned, the ekerite is much more advanced than the granite; in this respect ekerite would probably correspond to Drammen granite pegmatite (which, by the way, does not seem to exist, according to CHR. C. GLEDITSCH, who has studied the boundary relations of the Drammen granite in great detail). It is not improbable that the ekerite is really younger than the Drammen granite. As is well known, W. C. BRØGGER was not able to establish the age relation between these two rock types (3), and the matter is still undecided according to present experts on the geology of the Oslo rocks, e.g. Dr. CHR. OFTEDAHL.

Comparison of the Drammen granite with two well known Archaean granites*) as to Sr and Ba contents reveals the rather surprising fact that no real difference can be established, at least not by the analytical procedure employed here. See Fig. 2, which has been constructed in the same way as Fig. 1. In each rock specimen the alkali feldspar and the plagioclase have been examined separately. The purity of the samples for arcing was satisfactory, although it was sometimes difficult to obtain the plagioclase quite free from alkali feldspar. The alkali feldspars, of course, include perthite lamellae. It appears that in each granite the SrO content of the plagioclase is about equal to the BaO content of the alkali feldspar, and the BaO content of the plagioclase is about equal to the SrO content of the alkali feldspar. At the same time the first pair of concentrations is 5 to 10 times higher than the second pair. One should think that the absolute concentrations of Sr and Ba, and especially the equilibrium distribution of Sr and Ba between the two feldspar phases in a granite, would be sensitive to differences in the temperature of crystallization.

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*) Specimens of the Birkeland granite were kindly supplied by Mrs. B. NILSSEN.

If this is the case, it must be concluded that all the granites entered into Fig. 2 have crystallized at approximately the same temperature. This seems to be at variance with a number of other observations, which are commonly considered to indicate that the Drammen granite has crystallized at a considerably higher temperature than the Archaean granites: the alkali feldspar is orthoclase, it is devoid of Pb (4), the biotite is very poor in Sc (5), the contact aureoles are in pyroxene hornfelds facies, etc. It seems to me that these observations are so strongly in favour of a higher temperature of crystallization of the Drammen granite as compared with granites in gneiss areas, that I am inclined to conclude that the coefficients of distribution of Sr and Ba between the feldspar phases are approximately constant within the temperature interval in which granites may crystallize. Thus these coefficients can probably not be used as geologic thermometers in this interval, except perhaps if they could be determined very accurately.

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ON THE DEVELOPMENT OF GRANITE PEGMATITE IN GNEISS AREAS

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Abstract. In South Norwegian gneiss areas granite pegmatites are nearly always much poorer in Sr and Ba than are large granite bodies. Based on these and other observations the origin and emplacement of such pegmatites is discussed.

Certain aspects of this problem will be discussed here, mainly by means of the distribution of Sr and Ba in the feldspars of granites and pegmatites.

Sr and Ba were determined spectrochemically. The procedure has been described in some detail in an earlier paper [1]. It is well known that consistent spectrochemical determinations of Sr and Ba are difficult to obtain, because of the very slow evaporization of these elements in the arc. Therefore no high accuracy can be claimed for the results given below. However, as ascertained by a number of parallel exposures, they are relatively consistent. It may be that our figures are systematically too high [1], but this is of no consequence to the following considerations, which are based on relative Sr and Ba concentrations. The standard mixtures and the samples for arcing, as well as the spectrograms, were prepared by Mr. JENS HYSINGJORD, cand. mag.

The examined specimens are all from localities in the South Norwegian gneiss areas.

Granite pegmatite in plagioclase-quartz-gneiss in the island of Justøy.

The plagioclase gneiss complex in question has been the subject-matter of an earlier paper [2]. Granite pegmatite is a subordinate component of the complex and occurs in veins, bands and bodies of varying shapes and sizes. None of them are more than a few meters across, most of them are much smaller, sometimes barely visible in hand specimen. Along the strike direction even narrow pegmatite bands may be very persistent. Some of the bands have clearly been deformed, e.g. torn into boudins, during subsequent tectonic movements. The pegmatite bodies appear as more or less irregular patches and have not been notably influenced by tectonic movements; they must have developed at a later stage than most of the pegmatite bands, actually during the concluding phase of the movement. As pointed out in the earlier paper [2], the metasomatic origin of the alkali feldspar (microcline) is evident from field observations as well as from the constant appearance of myrmekite at the contact between the microcline and the plagioclase of the gneiss. It should be remarked that the gneiss itself, which consists of mainly plagioclase (about An_{30}) and quartz with usually subordinate amounts of biotite, does not contain visible alkali feldspar. It is obvious that the potassium metasomatism in the gneiss has been going on for a long time, and that the various pegmatites now observed demonstrate different stages of development. The incipient stages can be seen in the microscope: scattered microcline grains with myrmekite appear along certain narrow gneiss bands. In the next stage the microcline grains form continuous pink bands clearly visible in hand specimen, the grain size being still less than a millimeter. In the later stages the bands (or bodies) as well as the microcline (and quartz) grains continue growing in size, so that a normal pegmatitic appearance is eventually reached. Certain quite small pegmatite bodies may consist of one or a few comparatively large microcline grains, looking like porphyroblasts or augen in the gneiss. Even if the smallest pink bands or streaks have the appearance of aplite, they obviously do not differ from the larger pegmatites genetically. It is also generally observed that coarse grained pegmatite bodies have fine grained border zones. In the majority of cases the pegmatite is in immediate

Table 1. *Feldspars from the plagioclase gneiss complex of Justøy.*
n – number of samples examined.

		n	log p.p.m.	
			SrO	BaO
I. Plagioclase.				
a. From typical gneiss	1.	2	4.5	4.3
	2.	1	4.5	3.3
	3.	1	4.0	3.3
b. From gneiss close to pegmatite contacts	1.	1	3.8	3.0
	2.	5	3.8	2.7
	3.	1	4.2	2.7
c. From the interior of larger pegmatites	1.	2	3.8	3.2
	2.	1	3.8	3.0
	3.	1	3.7	2.7
	4.	1	3.3	2.2
	5.	2	2.3	2.0
II. Microcline.				
a. From pegmatite boundaries–	1.	2	4.0	4.5
	2.	2	3.5	4.2
	3.	5	3.0	4.0
	4.	1	2.8	3.8
	5.	2	2.7	3.7
	6.	4	3.0	3.7
	7.	2	2.7	3.5
	8.	1	2.7	3.3
	9.	1	2.3	3.3
b. From the interior of larger pegmatites	1.	1	3.3	4.0
	2.	2	3.0	4.0
	3.	5	2.8	3.5
	4.	1	2.8	3.3
	5.	1	2.7	3.3
	6.	5	2.7	3.0
	7.	2	2.6	2.7
	8.	2	2.3	2.7
	9.	2	2.3	2.5
	10.	1	1.8	2.2
III. Feldspars in actual contact.				
Plagioclase		3	3.8	2.7
Microcline			2.7	3.8

contact with the normal light plagioclase gneiss. In a few cases a contact pegmatite – amphibolite has been observed; then the amphibolite at the contact has been altered into a biotite-plagioclase-rock very rich in epidote and sphene. A rock of similar mineral composition, looking like biotite schist, occurs in narrow bands and small areas in the gneiss complex; it is supposed that this rock also has been formed from amphibolite by potassium metasomatism.

To some extent it has been possible, by means of the Sr and Ba contents of the feldspars, to follow up the gradual development of microcline pegmatite in the plagioclase gneiss. The results of the spectrochemical determinations are summarized in Table 1, which gives the observed concentrations in units of log parts per million.

Within each of the groups, (I, a) etc., the samples have been arranged according to decreasing contents of BaO. It is seen that this also corresponds roughly to decreasing contents of SrO. The range of concentrations observed is from more than 1% to about 0.01%. The predominance of SrO in plagioclase and of BaO in alkali feldspar is clearly demonstrated.

The plagioclase samples (I, a, 1) are so extremely rich in BaO that some comment is necessary. The rock is a fine grained nearly white gneiss occurring in narrow deformed bands embedded in very biotite-rich and strongly crumpled gneiss. Because of the high Ba content this light plagioclase gneiss might be suspected to contain much alkali feldspar. But this is not the case. In the spectra only moderately strong K lines are seen, and the microscopic examination reveals that microcline is a very subordinate constituent only. In addition this microcline exhibits quite normal refractive indices, far below balsam, so that it can not be anything in the direction of a hyalophane. It must be concluded that the observed BaO content is essentially a constituent of the plagioclase itself, i.e. that plagioclase may in certain circumstances contain as much as 1% BaO. In the present case it suggests itself that this high Ba content of the plagioclase results from an equilibrium distribution of Ba between the light gneiss and the surrounding dark gneiss: the light gneiss bands are only a few cm across, and the biotite of the dark gneiss also contains about 1% BaO. It is probable that the dark gneiss, which contains oligoclase-andesine, quartz, biotite, epidote, and much sphene, has been formed from an original amphibolite by K metasomatism, which has also affected the included bands of light plagioclase gneiss, some Ba being introduced along with the K.

The specimens (I, a, 2 and 3) are believed to represent well the country rock (ordinary plagioclase gneiss) showing no signs of K metasomatism. The samples do not contain visible microcline. The BaO contents are of the order of 2000 p.p.m. The plagioclase taken from gneiss close to pegmatite bands or bodies (specimens I, b) tend to be poorer in BaO than this, while the SrO contents are roughly on the same level as in the (I, a) samples. This may be due to a diffusion of Ba from the plagioclase into the alkali feldspar crystallizing in contact with it, in consequence of the tendency to establish an equilibrium distribution of the Ba between these feldspars. The alkali feldspars in question (samples II, a) will be discussed below.

The plagioclase specimens taken from the interior of larger granite pegmatites (samples I, c) exhibit highly variable Sr and Ba contents. Some of them (1, 2, 3) correspond closely to plagioclases of the groups (I, a) and (I, b) in this respect, while others (4, 5) tend to be much poorer in Sr and Ba. These plagioclases obviously did not originate in the same way. One would expect that they were all true constituents of the granite pegmatite, but this can hardly be the case. Field observations show that broader pegmatite bands often contain remnants of plagioclase gneiss bands in their interiors, and much of the plagioclase found in the pegmatites really belongs to the gneiss. Possibly some of this plagioclase has recrystallized in contact with microcline. At any rate it has to be expected that much of the plagioclase within pegmatite bands really belongs to group (I, b), gneiss in contact with pegmatite. This must be the case with samples (I, c, 1, 2, 3) and possibly (4). Probably only the samples (I, c, 5) are true constituents of pegmatite interiors. The matter will be further discussed below.

Among the microcline samples taken from pegmatite boundaries (II, a) number 1 is exceptional. It contains something like 1% SrO and 3% BaO. The specimen is a small lens-shaped body, a few cm in size, of rather coarse grained pegmatite, coated by a layer of biotite. This biotite, like that referred to above, is also rich in Ba, containing about 1% BaO. The very high Ba content of the microcline is obviously in equilibrium with that of the biotite. A look at the table shows that exceptional quantites of Sr and Ba were present during the formation of this small pegmatite lens.

The other microclines of group (II, a) exhibit BaO-concentrations varying from about 1% to about 0.2%, and SrO-concentrations varying from about 0.3% to about 0.02%, the variations for the two elements being roughly parallel. They probably represent various stages in the development of the pegmatite.

In the microclines from the interior of larger pegmatites (group II, b) the SrO and BaO contents vary in nearly the same way as in (II, a), but here still lower concentrations – down to about 0.01% for both elements – are rather common. The higher concentrations within this group may be interpreted as really belonging to microclines of group (II, a), microclines which have, it is true, been taken from the interior of pegmatites, but which are in contact with remnants of plagioclase gneiss, – see the above discussion of group (I, c).

A few samples of plagioclase-microcline-pairs, each taken from one hand specimen of a gneiss-pegmatite-contact, yielded fairly consistently the distribution of SrO and BaO between the two feldspars shown in (III). The plagioclase contains nearly 1% SrO and about 0.05% BaO, in good agreement with the plagioclases of group (I, b), and the microcline contains nearly 1% BaO and about 0.05% SrO, in fair agreement with the intermediate microclines of group (II, a). In some cases, not quoted in the table, the microcline yielded a higher percentage of SrO, but this seems to be due to a contamination of the samples by plagioclase. I consider the results given in Table 1 to be fairly representative of the equilibrium distribution under the conditions of formation in question, which correspond to low amphibolite facies. It may be of interest here to point out that similar Sr and Ba distributions have been observed between the feldspar phases of several large granite bodies (1). Table 2 illustrates this. The data are not very numerous, and in some cases very pure plagioclase samples could not be prepared. But it is seen that in each case the SrO content of the plagioclase is similar to the BaO content of the alkali feldspar, and vice versa, even if the levels of concentrations vary. It has been pointed out earlier (1) that this distribution of Sr and Ba seems to be fairly independent on the temperature of crystallization of the various

Table 2. Concentrations in units of log p.p.m. n–number of samples exam.

	n	SrO	BaO
Gneiss-pegmatite contact, Justøy.			
Plagioclase from gneiss	3	3.8	2.7
Microcline from pegmatite		2.7	3.8
Grimstad granite.			
Plagioclase	1	3.7	3.0
Microcline		2.7	3.5
Birkeland granite.			
Plagioclase	2	3.3	2.3
Microcline		2.7	3.5
Østfold granite.			
Plagioclase	4	3.3	2.3
Microcline		2.5	3.3
Drammen granite.			
Plagioclase	3	2.7	2.0
Orthoclase		2.0	2.7

granites. What is of interest at present is that the distribution of Sr and Ba between the feldspar phases of granites in gneiss areas, which must represent equilibrium, is nearly the same as the distribution between pegmatite microcline and the plagioclase of the gneiss in contact with it. This confirms that the latter distribution represents equilibrium. The newly formed microcline crystals in the plagioclase gneiss of Justøy therefore adjust their contents of Sr and Ba so as to be in equilibrium with those of the adjacent plagioclase crystals, and may also take some of the Ba from these crystals in order to approach equilibrium quicker. This of course should establish a Ba-concentration gradient in the near vicinity of the pegmatite, and some of the observations actually seem to confirm that such a gradient exists.

As shown by the series of data (II, a, b) and (I, c) of Table 1, there also exist concentration gradients for Sr as well as for Ba inside the pegmatites, and these gradients are very marked indeed. It is obvious that the larger pegmatites of the area are not at all in equilibrium as a whole as regards the distribution of Sr and Ba. The interpretation is clearly that these pegmatites have grown in size continuously or intermittently during a certain period of time, by introduction into their interiors of new microcline (and plagioclase) crystals. These crystals were comparatively very coarse, and probably formed rather quickly, so that equilibrium with the surrounding crystals could not be completely established. Since some of these large crystals are observed to be very poor in Sr and Ba – something like 100 times poorer than microcline crystals at pegmatite boundaries –, it must be concluded that the pegmatite-forming agent itself did not contain appreciable amounts of Sr and Ba. – The microcline (II, b, 10) of Table 1 would probably be in equilibrium with a plagioclase similar to (I, c, 5). In the field it is difficult or impossible to ascertain whether two pegmatite feldspars have crystallized simultaneously or not.

Since the pegmatite-forming fluid itself appears to have been originally extremely poor in Sr and Ba, the rather high average Sr and Ba contents of the pegmatite microcline must have been taken up from the plagioclase of the country rock. This raises some problems. There is no difficulty about the supply of Sr, since microcline usually takes up a small fraction only of the Sr present in the gneiss it is supposed to replace. On the contrary, if microcline replaces an equal volume of gneiss, incorporating some of the gneiss constituents, there will be a considerable surplus of Sr (and Ca etc.). Now the pegmatites and near environs do not contain any minerals (e.g. basic plagioclase or epidote) which might incorporate this surplus. Therefore the surplus of Sr etc., if it has existed at all, must have disappeared from the rocks forming the present surface. – As to Ba, the difficulty is that most of the pegmatite microcline contains much higher – perhaps on the average 5 to 10 times higher – percentages than the gneiss. Only a small fraction of the Ba actually present in the microcline could be supplied from equal volumes of gneiss. Therefore by far the greater part of the Ba must have accompanied K during the process of metasomatism. This is at variance with the conclusion reached above, that the pegmatite-forming fluid itself must have been originally very poor in Sr and Ba. To explain this discrepancy we may suppose that a K-rich fluid, originally without any Ba and Sr, moved a long way through plagioclase gneiss, possibly continuously crystallizing and recrystallizing, always in contact with plagioclase so that the above equilibrium distribution of Ba and Sr between the newly formed alkali feldspar and the plagioclase was readily established, until the position of the present rock surface was reached. In this way all the small pegmatite veins and bodies and the greater part of the larger ones might attain the high Ba contents observed, the pegmatite-forming fluid having been previously enriched in Ba during the passage through much more gneiss than corresponds to the present volumes of the pegmatites. When broad pegmatite bands had been formed, renewed metasomatic activity in the interior of these might be caused by fluids which had moved essentially through deeper parts of the pegmatite itself. New microcline crystals forming from these fluids would be in contact with older microcline crystals. If equilibrium were attained between such old and new crystals they would obviously be equal as to Ba and Sr percentages, that is, new alkali feldspar crystals formed through processes going on within the pegmatite itself only, must be successively poorer in Ba and Sr. In this way repeated formation of new microcline crystals within the larger pegmatites would explain the data presented in Table 1, (II, b). Field observations of bent gneiss bands, wawy biotite bands, and other irregularities within larger pegmatite bands [2], seem to confirm that the pegmatite bands have grown in width by introduction of new coarse material into the interior.

No direct replacement of plagioclase by microcline at pegmatite boundaries can be seen in thin section. What is observed is that myrmekite quartz gradually replaces plagioclase. Thus it appears that dissolution of the plagioclase is the process – or one process – that opens space for pegmatite in the gneiss. Therefore, when constituents of the plagioclase are incorporated in pegmatite minerals, this is probably by way of a fluid phase. Part of the constituents of the dissolved plagioclase must have disappeared from the present sites of the pegmatites.

The conclusion is inevitable that the pegmatites in this gneiss area, apart perhaps from the very narrowest veins and bands, did not originate through metasomatism in situ. Metasomatic reactions between a certain quantity of Ba-poor pegmatitic fluid and an approximately equal quantity of gneiss would not explain the high Ba-contents observed in most of the microcline. The pegmatitic fluid must have acquired practically all of its Ba content before reaching the present sites of the pegmatites, presumably at deeper levels in the gneiss. This means that the pegmatites, although evidently of metasomatic origin, must have been intruded into their present positions.

Large granite bodies like the Grimstad and Birkeland granites (Table 2), which are generally believed to be of metasomatic origin, also contain more Ba than would be expected to occur in equivalent quantities of the adjacent complex of various gneiss types, even if some of these types are granitic in composition. It is difficult to imagine in this case that the granitic fluids should have extracted Ba from quantities of mixed gneisses much larger than the granite bodies themselves. It is more probable here that the granitic fluid carried sufficient Ba already at deeper levels. Very deepseated igneous rocks generally seem to be rich in Ba (and Sr), even if they are not typical alkali feldspar rocks. Thus all the monzonitic rocks of the Oslo Region [1], which are supposed to have a deepseated origin because of the inferred high temperatures of their magmas, were found to contain about 0.5% BaO (which is something like 25 times the average content of the later granitic differentiates). Also anorthosite from the Egersund Region was found to contain about 0.5% BaO*) (and birkremite even more). The anorthosite usually contains less than 1% K_2O. Therefore, if most of the Ba were to replace K in the alkali feldspar (in antiperthite), this alkali feldspar would have to be a very Ba-rich hyalophane, which is highly improbable and not indicated by observations in thin section. It must be concluded that most of the Ba is incorporated in the plagioclase, which is thus unusually rich in Ba. On the other hand there must obviously be an equilibrium distribution of Ba between the plagioclase and the alkali feldspar of the anorthosite. As shown in Table 2 the distribution coefficient is nearly the same in the various granites, anatectic as well as truly magmatic, the BaO percentage in the alkali feldspar being some 5 to 10 times higher than that in the plagioclase. It is probable that a similar distribution coefficient applies to the anorthosite. In that case the alkali feldspar phase of the anorthosite would contain several per cent, perhaps as much as 5%, BaO. Thus ascending K-rich phases originating from anorthosite (and various other deepseated rocks) would be expected to be particularly rich in Ba. This would explain the existence of Ba-rich anatectic granites.

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*) V. M. Goldschmidt (Geochemistry, p. 252) quotes from von Engelhardt some rather low contents of Ba in anorthosite. My figures are much higher, but it is true that Egersund anorthosites are not included in Goldschmidt's list.

Granite pegmatite in other gneiss areas.

The next problem is to explain the origin of very Ba-poor granite pegmatite, which has been shown to occur in the interior of larger pegmatites and obviously represent late stages in the pegmatite formation. It was concluded above that the K-rich fluid forming all of the pegmatite in the gneiss of the Justøy area, was originally very poor in Ba. The study of pegmatite feldspar from other areas might supply a clue. We have examined samples from a number of pegmatite bodies situated in various parts of the gneiss areas of southernmost Norway. The majority of the specimens were collected many years ago by Olaf Andersen from deposits described by him and Tom. F. W. Barth [3], and kindly placed at my disposal by Professor Barth, Director of the Mineralogisk-geologisk Museum in Oslo. The results of the spectrochemical analysis are shown in Table 3. Here also the PbO contents of the alkali feldspar have been determined in most cases, and particularly strong Rb lines are shown in a qualitative way. It may be added that PbO was found only in 2 of the microcline samples from Justøy; the concentrations were low, not much higher than 10 p.p.m. Also, these feldspars do not contain unusual amounts of Rb.

The general outcome of Table 3 is that pegmatite feldspars are nearly always much poorer in Sr and Ba than granite feldspars. The Ba content of the microcline from Risøtangen is quite exceptional and must be due to local conditions. At the same time this sample is extremely poor in Sr. On the whole the fairly regular distribution of Sr and Ba between plagioclase and alkali feldspar observed in granites (Table 2) is hardly found in granite pegmatite. The distribution coefficients may be highly sensitive to variations in the temperature of crystallization within the interval in question, or equilibrium may not have been reached at all. I am inclined to believe in the latter alternative in most cases.

The pegmatites of the Iveland-Evje district and of Tørdal, which occur in gabbroic rocks within the Telemark granite area, are seen to be particularly poor in Sr and Ba and at the same time particularly rich in Pb and Rb. The Halvorsrød pegmatite in Østfold is somewhat similar. The amazonites (Landsverk, Landås, Tørdal) exhibit these properties most markedly. This group of pegmatites is rather opposite in character to the pegmatites of the Bamble-Kragerø district, which are on the average somewhat richer in Ba and Sr, and very poor in

Table 3. *Pegmatite feldspars from various Archaean areas.*

	log p.p.m.			Rb
	SrO	BaO	PbO	
I. Birkeland granite.				
Microcline	2.0	2.7	1.5	
II. Østfold granite, N. boundary.				
Microcline	2.0	2.3	2.0	
Plagioclase	2.3	2.0		
Microcline	1.7	2.0	1.7	
III. Østfold gneiss area.				
Halvorsrød.				
Plagioclase	1.8	1.5		
Microcline	<1.0	1.2	1.5	+
IV. Bamble – Kragerø district.				
Kjørstad W.				
Microcline	2.0	2.7	<1.0	
Toner.				
Plagioclase	2.5	1.2		
Microcline	2.0	2.7		
"Båten", Skåtøy.				
Plagioclase	2.3	2.0		
Microcline	1.8	2.5	<1.0	
Malmtangen.				
Plagioclase	2.0	1.8		
Microcline	1.5	2.5	«1.0	
Lille Furuholmen.				
Plagioclase	1.5	1.8		
Microcline	1.2	2.3		
Risøtangen.				
Plagioclase	2.5	2.0		
Microcline	<1.0	3.3	«1.0	
Kalstadgangen.				
Microcline	<1.0	2.0	«1.0	

Table 3, cont.

	log p.p.m.			Rb
	SrO	BaO	PbO	
V. Iveland – Evje district.				
Landsverk.				
Microcline	1.8	1.8	2.2	+
Høyland.				
Plagioclase	2.3	1.8		
Microcline	1.5	1.8	2.2	++
Pålsstien.				
Plagioclase	1.7	~1.0		
Microcline	1.5	1.5	2.2	+
"Salegruben".				
Plagioclase	1.8	1.8		
Microcline	<1.0	1.5	1.8	+
Landsverk.				
Amazonite	<1.0	~1.0	2.0	++
Landås.				
Amazonite	1.5	<1.0	2.0	++
VI. Tørdal, Telemark.				
Høydalen.				
Cleavelandite	<1.5	<1.0		
Amazonite	1.3	1.2	2.0	++
Skarsfjell.				
Amazonite	1.5	<1.0	2.3	++

Pb and Rb. Now the Birkeland granite and the Østfold granite contain much higher percentages of Sr and Ba than their endogenous pegmatites (Tables 2 and 3), and also less Pb. This confirms that granite pegmatite is impoverished in Sr and Ba and enriched in Pb (and a number of other elements) as compared with its mother granite. The process of development of granite pegmatite from a mother granite may eventually lead to pegmatites extremely poor in Sr and Ba and often rich in Pb, Rb, etc. It seems to me that the Iveland-Evje and Tørdal (and also Halvorsrød) pegmatites must represent very advanced stages of such a development, and the Bamble-Kragerø pegmatites somewhat less advanced stages. As pointed out above it is very difficult to explain the deficiency in Sr and Ba on the supposition that the pegmatitic fluids should have risen directly from great depths.

Large anatectic granite bodies must have formed, presumably below the present surface, and the pegmatites must have developed from them. I believe all the pegmatites discussed in this paper must have formed in this manner, by way of large anatectic mother granites.

SUMMARY

Large presumably anatectic granite bodies like the Birkeland granite contain much more Ba than could in general be derived from equal volumes of mixed gneisses. Such granite bodies may represent K-rich derivatives of very deepseated rocks, e.g. anorthosite and related rocks, which may actually be very rich in Ba. Granite pegmatite bodies endogenous in mother granites have been found to be much poorer in Sr and Ba than the granite proper. Other granite pegmatites are in general still poorer in Sr and Ba. Pegmatites nearly deficient in Sr and Ba seem to represent the most advanced stages of pegmatite formation from a mother granite; these pegmatites are also usually enriched in Pb, Rb, and other pegmatitic elements. It seems justified to conclude that all the pegmatites discussed in this paper must derive from large mother granite bodies, which may themselves be rather rich in Sr and Ba. As to the small pegmatitic veins, bands and bodies in the plagioclase gneiss of the Justøy area, it appears that the pegmatitic fluid was also here originally extremely poor in Sr and Ba, but that most of it absorbed Ba (and Sr) from the plagioclase during the passage through the gneiss, until an equilibrium distribution was more or less established, a distribution similar to those found between the feldspar phases of granites. It is evident that these pegmatites could not have been formed through metasomatism in situ; the pegmatitic fluid must have moved bodily through the gneiss, metasomatic processes going on all the time.

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THE ORIGIN OF FELDSPAR INCLUSIONS IN THE LAMPROPHYRES OFF KRISTIANSAND, SOUTH NORWAY

A preliminary note

BY

HARALD CARSTENS

T. BARTH (1944) some years ago called attention to associated lamprophyric and diabasic dikes west of Kristiansand on the coast of Norway.

The lamprophyres occur as a rule as flatlying, slightly undulating dikes ranging up to 2 m in width. More steeply dipping sill-like intrusions are, however, not unusual.

A marginal banding is sometimes very conspicuous in the broader dikes. The banding is due to the presence of internal, chilled contacts, symmetrically disposed on each side of the dikes, fig. 1. The width of the bands varies as shown in the figure.

The narrow dikes may contain a thin central band sharply limited from the margins, fig. 2. These bands have a glassy groundmass in which abundant phenocrysts of hornblende occur. P. ESKOLA (1954) has described a similar band in a narrow lamprophyre dike at Helsinki.

The chilled contacts suggest that the lamprophyric magma was repeatedly injected into the opening fissures. According to J. H. HAFF (1939) the relations between the successive dike intrusions are intrasectate, as the younger dikes lie within the older ones. Similar intrasectate multiple dikes occur in the Arendal region, some 60 km east of Kristiansand.

The lamprophyres are characterized by red vesicular inclusions containing predominantly red anorthoclase, fig. 3. The feldspar is

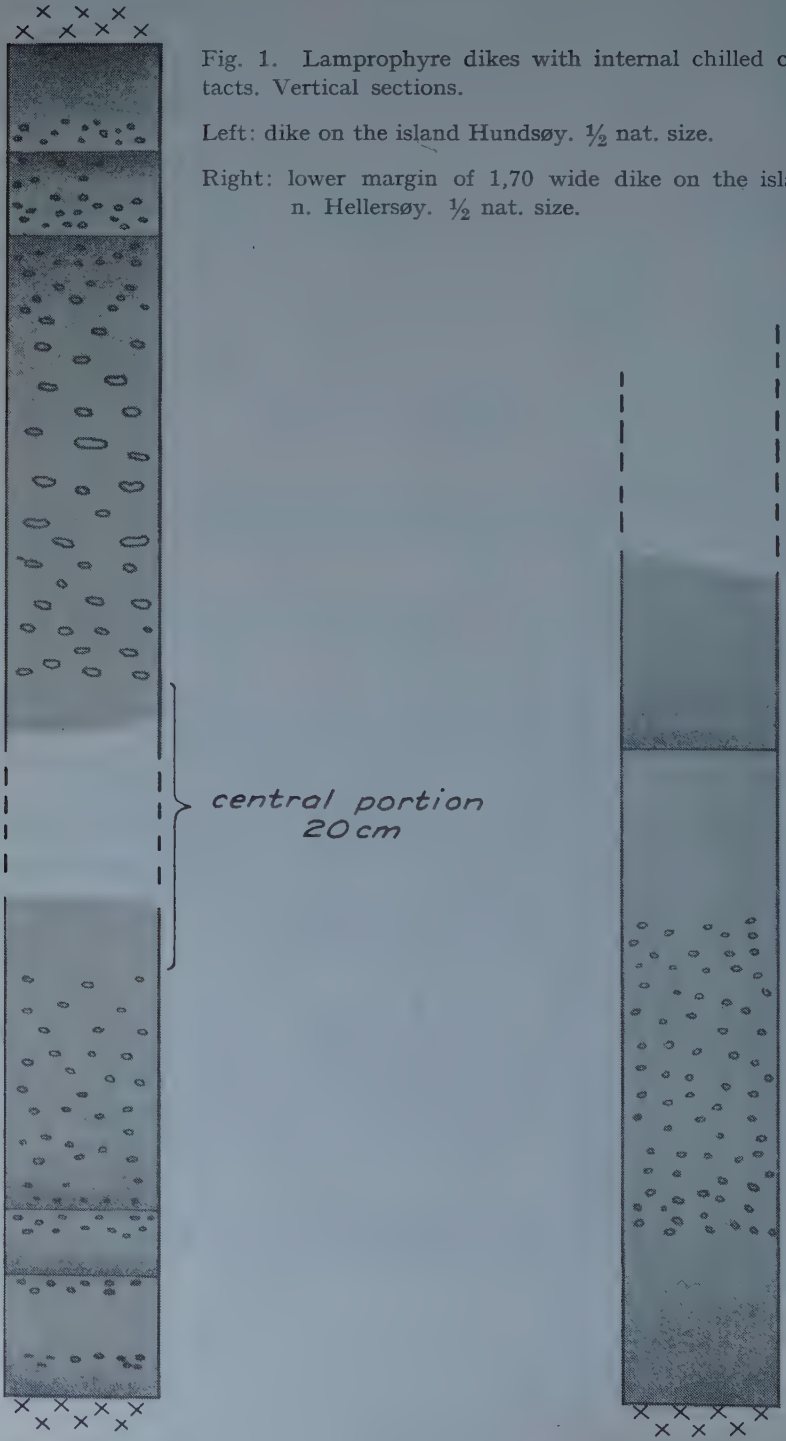

Fig. 1. Lamprophyre dikes with internal chilled contacts. Vertical sections.

Left: dike on the island Hundsøy. ½ nat. size.

Right: lower margin of 1,70 wide dike on the island n. Hellersøy. ½ nat. size.

heavily clouded with a brown pigment. Needles of brown hornblende may protrude from the groundmass into the large vesicles, the lower part of which, however, commonly is devoid of hornblende, fig. 4. The hornblende-bearing vesicles have a composition analogous to larger irregular patches of leucocratic lamprophyre. The vesicles are commonly filled with a core of calcite and fibrous, radiating chlorite. Pyrite is frequently present. The lath-shaped feldspar indiviuals are frequently arranged in fan-like groups, fig. 5. The flattening of the vesicles is as a rule parallel to the walls.

The distribution of the feldspar inclusions is rather interesting, fig. 1. They are concentrated towards the marginal portions of the dikes, and only a few scattered vesicles occur in the central parts. The size of the vesicular inclusions always decreases towards the chilled contacts. It is also worthy of notice that the vesicles are largest in size near the hanging wall, commonly exceeding 5 mm in length.

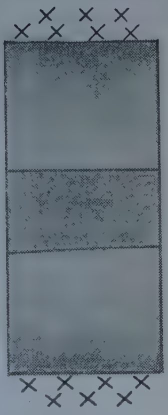

Fig. 2. Narrow lamprophyre sill with central glassy band on the island Skarvøy. Vertical section. Nat. size.

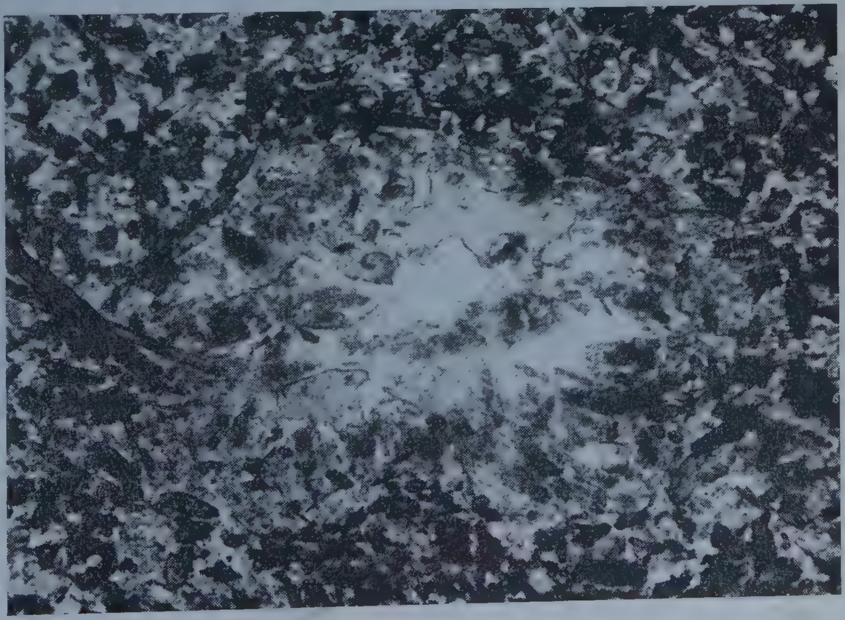

Fig. 3. Feldspar inclusion (ocelli) in the lamprophyre dike on the island Tjamsøy. 64 x.

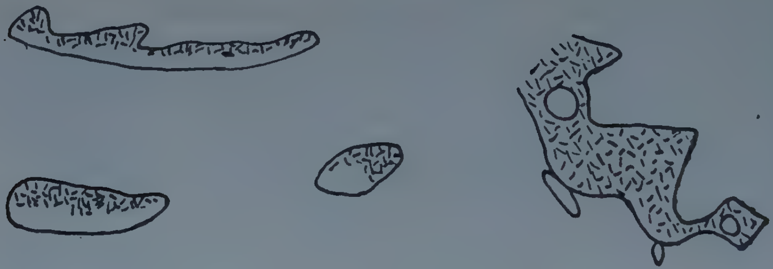

Fig. 4. Left: Vesicular inclusions containing hornblende (2 x nat. size). Right: Irregular patch of leucocratic lamprophyre with circular feldspar ocelli.

Almost identical feldspar inclusions in Swedish lamprophyres (kullaites) have been described by S. Hjelmqvist (1930 and 1939). Hjelmqvist who first considered the inclusions as amygdales, in his last paper abandoned this hypothesis, and assumed them to represent fragments of country rock syenitized by the enclosing magma. T. Barth (1944) suggested a similar origin for the red inclusions of the Kristiansand lamprophyres.

Amygdaloidal and ocellar structures are rather common in the associated diabases of the Kristiansand region. The chlorite- and calcite-filled amygdales decrease in size towards the chilled selvages, and sometimes they are arranged in parallel rows. The more complex ocelli, fig. 6, usually have a kernel of calcite, chlorite and feldspar spherulites, which is surrounded by a zone of lamprophyric composition. It is important to note that the feldspar around the ocelli is tangentially arranged, showing that the ocelli were formed before the enclosing magma was completely solidified. Similar feldspar-rich ocelli are found in the aforementioned Arendal dike.

So many points of resemblance are found between the feldspar inclusions of the lamprophyres and the ocelli just described, that they naturally must be attributed to a similar mode of origin.

Reviewing the lamprophyre literature it becomes evident that analogous ocelli and feldspar vesicles are very common in lamprophyres. Very similar ocelli have lately been described and pictured by E. A. Vincent (1953), and E. Sæther (1947) has shown that related vesicles occur in lamprophyres of the Oslo region. I will also refer to the recent papers by A. Knopf (1935), H. W. Jaffe (1953) and J. G. Ramsay (1955).

D. L. Reynolds (1935) has proposed that ocellar structures in lamprophyric rocks in general may be due to the transfusion of quartzitic inclusions. The vesicular feldspar inclusions and the ocelli of lamprophyre or diabase are different, however, from inclusions of granitic country rock, epixenolithic in character, which likewise occur in lamprophyres and diabases. These xenoliths are not very abundant, they vary in size, and seem to have suffered no alteration by their immersion in the magma. The lamprophyres are commonly chilled against the xenoliths. A xenolithic origin of the feldspar inclusions appears to be more likely if it be assumed that they represent inclusions which have travelled with the magma for a long distance.

The resemblance to ordinary calcite- and chlorite-filled amygdales, on the contrary, ties the formation of the feldspar inclusions and the ocelli to the magmatic stage. In fact, the only difference of some

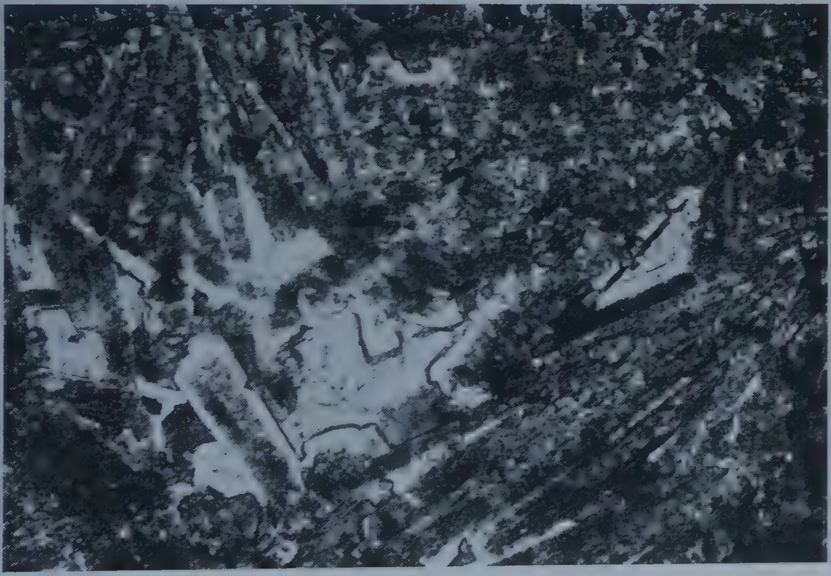

Fig. 5. Feldspar inclusion (ocelli) in the lamprophyre dike on the island Tjamsøy. Fan-shaped arrangement of the feldspar. Calcite in the center. 64 x.

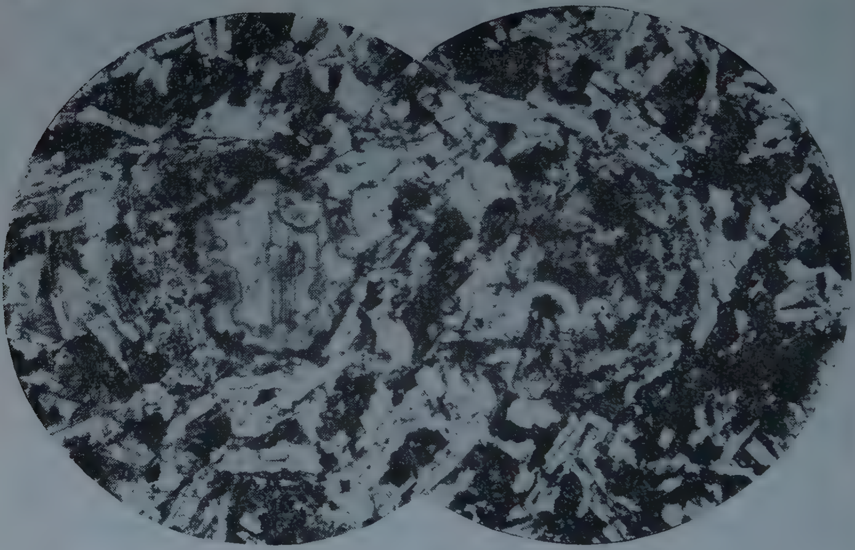

Fig. 6. Ocellar structures in diabase on the island Tjamsøy. 29 x.
Left: kernel of chlorite and feldspar.
Right: kernel of calcite and chlorite.

importance between the feldspar inclusions (or the ocelli) and the amygdales are their mineralogical composition. The presence of feldspar in the ocelli show that they were formed at a higher temperature than the amygdales. That the ocelli were formed earlier than the amygdales was also demonstrated by the tangential orientation of the feldspar around the ocelli. The leuco-lamprophyric patches in the normal lamprophyre furthermore form a link between the lamprophyre and the feldspar inclusions.

The authors referred to above (VINCENT, SÆTHER, KNOPF, JAFFE and RAMSAY) agree in a late magmatic origin of the ocelli described by them.

The claim that the red feldspar inclusions were formed at the magmatic stage, does not disprove a hybrid origin of the lamprophyres in question, though I believe that it weakens the theory of hybridization. Furthermore, the fact that potash predominates in the granitic country rocks, whereas the lamprophyres characteristically are soda-rich, also goes against hybridism.

It seems to be an indisputable fact that true xenoliths are remarkably common in lamprophyres. In some cases, however, I believe that magmatic ocelli or late-stage leucocratic segregations wrongly have been taken for xenoliths. For example REYNOLDS' description (REYNOLDS 1938) of "quartz xenoliths with feldspatic replacement rims" may well represent quartz-filled ocelli of the type described by H. VON ECKERMANN (1928).

However, it is also true that lamprophyres with no traces of xenoliths whatsoever, occur as well, commonly in association with diabases. The finding of VINCENT (1953) of lamprophyric ocelli in the diabases associated with the Skaergaarden lamprophyres (analogous to the ocelli in the Kristiansand diabases) is highly suggestive of a basaltic parentage.

Certainly, no single solution to the "lamprophyre puzzle" can be offered, see for example CHR. OFTEDAHL (1957). Hybridism, fractional crystallization of basaltic magmas and simple heteromorphism are all possible causes for the development of lamprophyric rocks.

The manuscript was critically read by prof. T. BARTH.

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NOTISER

A Note on the Distribution of Ferrides in Accumulative Titaniferous Iron Ores.

BY

HARALD CARSTENS

With analyses by B. Bölviken and K. S. Vestre

A titaniferous iron ore deposit in the West-Norwegian gneiss area has recently been described by the author (1). The origin of the ore was considered due to the accumulation of magnetite during a stage of the crystallization period when appreciable amounts of titaniferous magnetite separated from the magma as a primary precipitate.

Similar ores are known to occur at Taberg and Ulvön in Sweden (2) (3), and on Rhode Island, U.S.A. (4). As the Ulvön deposit seemed to be especially favourable for a study of the trace element distribution due to the non-coronitic texture of the ore, thus rendering a clean separation of the mineral constituents possible, some analyses have been carried out at Statens råstofflaboratorium, Trondheim. Samples of the Ulvön ore were collected during a short visit to the island in 1956.

The ore horizon and the adjacent wall rock at Grunna on Ulvön are of a troctolitic composition as revealed by the modes on p. 580 in MOGENSON's paper (3). The difference between the high grade ore and the lean wall rocks is due to a variation in the proportions of olivine, plagioclase and magnetite, the latter being strongly enriched in the ore.

The texture of the ore is visualized in fig. 1. The plagioclase shows a well preferred orientation, 010 being paralell to the ore boundaries. The long direction of the olivine crystals, elongated parallel to the c-axis, as a rule also lie in that plane. A very distinct planar structure is consequently produced in the rock. The idiomorphic habit of the magnetite is demonstrated by the figure, and thus all the main constituents of the ore – magnetite, olivine and plagioclase – indicate according to texture that they arrived early at the place of consolidation.

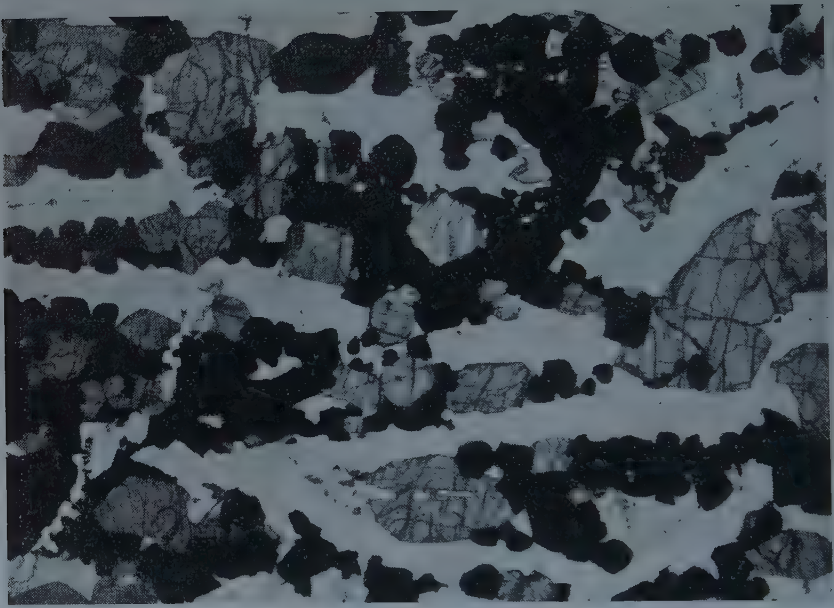

Fig. 1. Magnetite-troctolite (high grade ore), Ulvön. 11 x.

The augite, when present, has an ophitic relation to the plagioclase (the texture is coron-ophitic according to WELLS (5), as a core of olivine usually is enclosed in the augite). Small inclusions of magnetite and plagioclase may occur in the olivine.

The texture is interpreted as follows (fig. 2). Olivine and magnetite accumulated in a part of the magma in which phenocrysts of plagioclase already existed. A small amount of interstitial liquid crystallized to give plagioclase, augite, biotite and apatite. Due to the continued growth of plagioclase from the rims of the existing phenocrysts, the idiomorphic habit of the magnetite and the olivine against the outer part of the plagioclase was developed.

PHENOCRYSTS (formed *in situ*)	*Plagioclase*	
ACCUMULATED PHENOCRYSTS	*Olivine* *Magnetite*	
INTERSTITIAL LIQUID		*Plagioclase* *Augite* *Biotite* *Apatite*

Fig. 2.

Table 1. *Spectrographic analyses of the ferrides in the dolerite and the ore deposit of Ulvön.*

	TiO_2	V	Cr	Co	Ni	Mn
Magnetite, high grade ore	22.4[1]	0.66	0.20	0.022	0.025	0.30
« low grade ore	21.2[1]	0.68	0.11	0.021	0.022	0.27
« dolerite		0.24	0.005	0.011	0.005	0.40
Olivine, high grade ore	0.19	0.020	—	0.021	0.030	0.23
« low grade ore	0.11	0.029	—	0.020	0.027	0.36
Augite, dolerite	2.5	0.017	—	0.006	—	0.15
Plagioclase, high grade ore		—	—	—	—	0.004
« low grade ore		—	—	—	—	0.004
« dolerite		—	—	—	—	0.005

[1] Determined by chemical methods.

— indicate that concentration of the element is less than 0.005 %.

The analyses are presented in the table below. It clearly shows that the contents of the ferrides, except Mn, is higher in the magnetites which crystallized early. The enrichment of Mn, in the late magnetites is expected owing to the great radius of its ion, being larger than any other of the ferrides. LUNDEGÅRDH (6) has suggested that the Ni/Co ratio may indicate the stage of fractionation, and this agrees well with the present results, cobolt and nickel being reduced with a factor of 2 and 5 respectively in the late magnetites.

Vanadium and chromium are unable to enter into the lattice of olivine in any abundance, but are rapidly removed from the magma when magnetite precipitates, V^{3+} and Cr^{3+} being camouflaged by Fe^{3+}. The low contents of vanadium and especially chromium in the augite, in which these ions easily may find a place in the structure, demonstrates the effectiveness of the vanadium – chromium removal in the early magnetites.

Nickel, on the other hand, may go into the olivine as well, there being camouflaged by Fe^{2+} or Mg^{2+} (7). The distribution of nickel between magnetite and olivine, which precipitated from the magma at the same time, depends therefore upon the ease of entry in these structures. The olivine of the Ulvön ore has a little higher content of nickel than the associated magnetite, but the reverse relation applies to the Taberg ore (2). Accordingly nickel seems to enter olivine (hyalosiderite) and magnetite with about the same ease. Nickel has been almost entirely removed from the magma at the early stage, shown by the small contents of nickel in the augite.

Plagioclase apparently is able to incorporate some Mn in the lattice.

It is rather interesting that the ulvöspinel, found by Mogenson in this ore some years ago (3), is present in the high grade ore only. In the magnetites of the low grade ore, which have only a slightly lower TiO_2 content, ulvöspinel is entirely absent and martite appears. Lamellae of ilmenite and hercynite are present in both magnetites. VINCENT (8) has pointed out that the presence of ulvöspinel is related to a low oxidation state of the magnetite. According to FOSLIE (9), the ulvöspinel is not stable in the presence of Fe_2O_3: $Fe_2TiO_4 + Fe_2O_3 = Fe_3O_4 + FeTiO_3$. The disappearance of ulvöspinel in the hematite-bearing magnetite confirms the antipathetic relations between ulvöspinel and hematite.

VINCENT and PHILLIPS (8) suggested that oxidation by the interprecipitate magma, being more abundant in the ulvöspinelbearing bands, was responsible for the formation of ilmenite at the expence of ulvöspinel. The study of the Dopma titanic iron ore in Norway (1), supported this conclusion. At Ulvön, however, the only difference of some importance between high and low grade ore is the proportions of the main minerals. This speaks in favour of a primary difference in the oxidation state of the magnetites. That a temperature difference might have been the controlling factor is indicated by the lower contents of the Fa-molecule in the olivine associated with the mogensenite (ulvöspinel-bearing magnetite). According to chemical analyses the composition of the olivine is Fa 36 and Fa 41 in the high and the low grade ore respectively.

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Note on the distribution of some minor elements in coexisting ortho- and clino-pyroxene

BY
HARALD CARSTENS

With analyses by K. S. Vestre and R. Solli

Orthorhombic and monoclinic pyroxene have been successfully separated in two Norwegian hypersthene-gabbros and in a banded basic inclusion in one of them. When treated with methylene-iodide (sp.gr. 3.3), the clinopyroxene floated in contrast to the orthopyroxene which accumulated at the bottom. A purification of these concentrates was obtained with a Franz Isodynamic Separator due to the higher magnetic succeptibility of the orthopyroxene.

To test the influence of the major elements on the minor element distribution, some determinations of Al, Mg and Fe have been included in table I. Not enough pyroxene was separated for complete analyses. Two analyses of pyroxenes from a banded gabbro in Lofoten are shown in the table, though the concentrates obtained were not of sufficient purity.

The trend of the distribution of the minor elements is well demonstrated for five of the ferrides. Ti, Cr, V and Fe^{3+} are enriched in the clinopyroxene, Mn in the associated orthopyroxene.

The high contents of Al in the orthopyroxene are noteworthy. Al is divided between tetrahedral and octahedral coordinations in pyroxene. Due to the works of WAGER and DEER (1939), EDWARDS (1942), NOCKOLDS and MITCHELL (1948) and MUIR (1954) it is well known that the orthorhombic pyroxene is relatively enriched in iron compared to the associated monoclinic pyroxene. This is confirmed by the present analyses, table II. According to RAMBERG (1952) this indicates that the amount of tetrahedrally coordinated Al is greater in the rhombic than the monoclinic pyroxene, but this is contrary to experience. NOCKOLDS and MITCHELL (1948) have suggested that Al in tetrahedral position controls the distribution of the three-valent trace elements in coexisting pyroxenes, thus balancing the positive charges introduced in the Y-group by the three-valent ions. In the present case, Al replaces Si in the orthopyroxene as well, and electric neutrality will be maintained in the lattice even by quite large substitutions of Cr^{3+} and V^{3+}. It is knovn that Ti^{4+} and Fe^{3+} may replace Si in the pyroxenes (KUNO 1955), and it seems to be a natural assumption that Al^{3+}, Fe^{3+}, Ti^{4+}, Cr^{3+}, and V^{3+} divide themselves between tetrahedral and octahedral positions in the pyroxenes according to

Table I. Analyses of associated orthorhombic and monoclinic pyroxenes.

	Al_2O_3	Fe_2O_3	MgO	FeO	Ti	Cr	V	Ni	Co	Mn	Nγ
Orthopyroxene, hyp.-gabbro, Skjaekerdal .	3.20	0.20	25.20	15.48	0.36	0.05	0.02	0.07	0.011	0.27	1.693 ± 0.002
Clinopyroxene, « « «	4.79	0.34	15.80	7.19	0.84	0.11	0.04	0.10	0.011	0.14	1.697 ± 0.002
Orthopyroxene, hyp.-gabbro, Raana	2.66	0.42	25.57	15.50	0.38	0.16	0.04	0.04	0.010	0.19	1.695 ± 0.002
Clinopyroxene, « « «				6.98	0.72	0.25	0.08	0.05	0.007	0.05	1.698 ± 0.002
« « « «					0.90	0.25	0.07	0.02	0.006	0.10	
Orthopyroxene, saxonite, «					0.30	0.23	0.03	0.03	0.009	0.12	
Orthopyroxene, banded inclusion, Raana ..				12.98	0.37	0.06	0.03	0.02	0.009	0.28	1.687 ± 0.002
Clinopyroxene, « « « ..	3.73	0.26	16.30	5.72	0.49	0.07	0.06	0.01	0.005	0.14	1.687 ± 0.002
Orthopyroxene, banded gabbro, Lofoten ..					0.25		0.01	0.005	0.009	0.40	1.707 ± 0.002
Clinopyroxene, « « « ..					0.50		0.02	0.006	0.008	0.24	1.712 ± 0.002

The minor constituents are determined spectrographically.

Table II. Iron enrichment of coexisting pyroxenes.

	$\frac{Fe}{Fe+Mg}$	atomic %
Orthopyroxene, hyp.-gabbro, Skjaekerdal	.26	
Clinopyroxene « « «	.20	
Orthopyroxene, banded inclusion, Raana	.20	
Clinopyroxene « « «	.16	

physical and chemical conditions prevailing at the time of their formation. These ions are more easily accepted in the structure of the clinopyroxene.

Mn follows Mg^{2+} and Fe^{2+}, and the contents of the latter divalent ions are always highest in the orthopyroxene, The amount of Mn in the orthopyroxene is approximately twice as high as the clinopyroxene, and so are the contents of $Mg^{2+} + Fe^{2+}$.

Assuming that Ni and Co substitute for Mg^{2+} and Fe^{2+}, we should expect an enrichment of these elements in the orthopyroxene. The failure, however, to determine exactly the behavior of Ni and Co is probably due to admixed particles of pyrrhotite and pentlandite. As these sulphides seemed to be absent in the banded inclusion of the Raana gabbro, the analyses of the pyroxenes separated from this ought to be the most reliable. Thus there may be some indication of an enrichment of Ni and Co in the orthopyroxene. Regarding the distribution of Ni among the pyroxenes, we are faced with a problem known to all petrologists: the association of nickelbearing sulphides and norites. SHAND (1950) believed that Ni originally was concentrated in the magnesian minerals of the noritic rocks. And SULLIVAN (1948) suggested that the orthopyroxene possibly was unable to incorporate as much Ni as the monoclinic pyroxene, making Ni available for ore deposition. Sullivan's proposition does not find support from the present investigation.

Visual examination of the spectrographic plates shows that Ga (camouflaged by Al) and Sc (substituting for the pair (Mg, Fe) or Ca) are enriched in the clinopyroxene of Skjaekerdalen, whereas Mo and Pb is slightly enriched in the associated orthopyroxene. Zr was not present in detectable amounts.

Thanks are due to Prof. T. F. W. Barth for helpful suggestions.

Statens råstofflaboratorium, november 1957.

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Trondheims-feltet—Gneisområdet—Jotunheims-området.

Bemerkninger til Ivar Hernes's avhandling.

Summary: In a recent paper in this journal by Ivar Hernes on "Connections between the Trondheim and Sunnhordland Regions, Caledonides of Norway" Mr. Hernes maintains that the Trondheim Region has its continuation in the north-western gneiss area of southern Norway, and, secondly, that the Jotunheim Region occupies a less central position in the Caledonian orogen than the Trondheim Region. There is nothing to object to this. The same views were brought forward for the first time about 20 years ago by Olaf Holtedahl and must now be said to be generally accepted. But Mr. Hernes is to blame for not duly having cited the writings of Holtedahl and subsequent writers on the same subject. A reader not well acquainted with Norwegian geology and litterature must get the impression that the concepts mentioned above were new and invented by Mr. Hernes.

I de to første perioder i sin siste avhandling skriver Hernes (1957, s. 247): "The traditional view put forward in Norwegian geological discussions has been to draw the links between the Trondheim region and the coastal area south of Bergen over the Jotunheim region. On the other hand an essential difference has been claimed to exist between the Trondheim region and the Jotunheim region." Dette tyder på at Hernes har vært klar over at andre før ham har oppfatninger som avviker fra det han kaller det tradisjonelle syn på de spørsmål det her gjelder. Men på flere hovedpunkter i sin avhandling fremsetter Hernes synsmåter som de skulle være hans egne, uten å nevne at samme synsmåter tidligere er blitt hevdet av andre forskere. En leser av avhandlingen som ikke er orientert i norsk geologi og dens litteratur må få det inntrykk at disse synsmåter er nye og Hernes's egne.

Hernes's hovedtese er for det første at Trondheims-feltet tektonisk sett har sin fortsettelse i det vestlige (nordvestlige) gneisområde (s. 248, annet avsnitt ovenfra), han refererer her til et av sine tidligere arbeider (Hernes 1956), og for det annet at Jotunheims-området har en mindre sentral stilling i Kaledonidene enn Trondheims-feltet og at det i tektonisk henseende kan sammenstilles med Sparagmittområdet.

Det er forbausende at Hernes kan skrive dette uten å nevne Olaf Holtedahls påpekning, for omkring 20 år siden, av at gneisen i det nordvestlige området i Sør-Norge er "bunngneis" som uten tydelig grense går over i Trondheims-feltets omvandlete sedimeter og underliggende eo-kambriske avleiringer (Holtedahl 1936, 1938). Og om Hernes ikke hadde gått lengere tilbake i litteraturen enn til 1953, måtte han i all fall være blitt oppmerksom på Tore Gjelsviks avhandling fra dette år, hvor sammenhengen mellom Trondheims-feltet og gneisområdet er inngående behandlet og klart kartmessig fremstillet.

Om Jotunheims-områdets stilling skriver Hernes (s. 252): "Following my concept the region occupies a less central position in the mountain chain than the Trondheim region and Sunnhordland, and a better paralell can be drawn with the Sparagmite formation." Dette er heller ikke noe nytt. Holtedahl har i en avhandling fra 1944 fremhevet at Jotunheims-området mangler intrusivbergarter og kisforekomster av Trondheims-feltets type fordi det har ligget for langt borte fra den sentrale del av den orogene sone. Selv har jeg (1951, s. 11) gitt en kartfremstilling av de forskjellige hovedfacies av de kambro-ordoviciske avleiringer i Sør-Norge, hvor motsetningen mellom overskyvningsområdet Jotunheimen – Hardangervidda på den ene side og Trondheims-feltet på den annen side klart kommer frem. For å komme med en personlig bemerkning, kan det godt ha eksistert sedimenter av Trondheims-feltets facies i Jotunheimen. Men de må i så fall ha vært tilstede som fremskjøvne dekker som senere er blitt vekkerodert.

Det er videre noe overraskende at Hernes på tre steder i sin avhandling (s. 248, s. 253) skriver at vi i Jotunheims-området har "nappes overlying pre-Eocambrian rocks". Hernes må vel som alle vi andre vite at de bergarter som dekkene hviler på er av kambro-silurisk eller tildels av sparagmittisk alder. Hans mening må være at vi under dekkene og de underliggende sedimenter har uforandret grunnfjell som i høyden er en del tektonisk påvirket. Noen klar og entydig uttrykksmåte bruker han her ikke.

En annen feil av rent formell art gjør Hernes ved å sidestille "Trondheim region" og "Sparagmite formation", en regional og en stratigrafisk enhet.

Hernes's avhandling er et oversiktsarbeide som ikke bringer noe nytt stoff. Nettop i slike avhandlinger bør forfatteren ha en særlig plikt til å referere tidligere forskeres resultater og synsmåter.

Trygve Strand.

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Trykt August 1958.

Den kaledonske fjellkjedes hovedretning mellom Trondheim og Stavanger.

Svar til Trygve Strands bemerkninger.

Summary: In my paper "Connections between the Trondheim and Sunnhordland Regions, Caledonides of Norway", in this journal, I discuss features which throw light on the relationship between an arcuate Caledonian mountain range and the geology of Central and Southern Norway.

In this reply to dr. TRYGVE STRAND'S comments is shown that there is no essential difference between OLAF HOLTEDAHL'S view according to the primary trend of the Caledonides, and the cited and discussed ideas of THOROLF VOGT. It can be mentioned here that the first publication I refer to in my paper is a lecture given by VOGT 30 years ago. Nor can I see that any other geologist has discussed the idea of an arcuate Caledonian mountain range advocated in my paper.

Redaktøren av Norsk Geologisk Tidsskrift har vist meg professor Trygve Strands manuskript, slik at mitt svar kan bli trykt sammen med Strands bemerkninger.

I min avhandling "Connections between the Trondheim and Sunnhordland Regions, Caledonides of Norway", nedenfor referert til som Connections, diskuterte jeg Den kaledonske fjellkjedes hovedretning i Midt- og Syd-Norge. Jeg drøftet trekk som viser at Kaledonidene fra Trondheimsfeltet fortsetter i VSV-lig retning til Vestlandets devonsynklinalområde, og herfra i S-lig retning langs Vestlandet.

La oss først se på det VSV-lige foldesystem. Her refererer jeg i første rekke til TH. VOGT. Jeg vil sitere hva Vogt skriver i sin fascinerende Revolusjonshistorie (1928, s. 113). Vogt diskuterer den postkaledonske foldningsfase som han nederst på samme side kaller Svalbard-foldningen, og henleder samtidig oppmerksomheten på forbindelsen mellom Trondheimsfeltet og Vestlandets devonsynklinalområde. VOGT skriver:

„Stort sett kan vi betrakte den som en posthum foldning i forhold til den egentlig kaledoniske, d.v.s. den følger stort sett de gamle retnings-systemer, opretholder så å si de gamle tradisjoner. Men i mange trekk forholder den seg renegat som STILLE har kalt det, d.v.s. den skjærer over gamle foldningsakser og er altså opposisjonell mot de gamle retninger.

Jeg mener i det hele at denne fjellkjedefoldning griper dypt inn i det gamle underlag, ikke bare der hvor devonfeltene ligger, men overalt langs Norges vestlige kyst fra Vestlandet til Finnmark. Fra Trondhjems-leden er der enkelte merkelige detaljer som viser dette og jeg kan nevne at Bergensfeltenes devonsynklinaler synes å fortsette over til eiendommelig flikformete synklinaler langs Trondhjemsfeltets vestgrense. Man har i virkeligheten to forskjellige foldningsystemer som krysser hinannen her, nemlig Trondhjemsfeltets store synklinal, og en serie smale synklinaler i WSW–ONO, og det tør være et spørsmål om ikke de siste som helhet eller for en vesentlig del er av yngre alder."

Jeg refererer dette, både fordi det danner utgangspunktet for min Connections, og er referert sammen med tre andre avhandlinger på første side i Connections, og fordi O. HOLTEDAHL i sin Norges geologi, Bind I, s. 478, tar stilling til Vogts diskusjon. HOLTEDAHL skriver:

"Th. Vogt har hevdet [Revolusjonshistorien] at de post-orkadiske bevegelser vi her beskjeftiger oss med "griper dypt inn i det gamle underlag, ikke bare der hvor devonfeltene ligger, men overalt langs Norges vestlige kyst fra Vestlandet til Finnmark" (s. 113); og nærværende forfatter finner det ikke urimelig at så kan ha vært tilfellet. Bevegelsene kan sannsynligvis betraktes som en slags kaledonske attpå-bevegelser."

Denne kommentar viser at Holtedahl er enig i Vogts diskusjon, med det VSV-lige foldesystem som en yngre dannelse, og at fjellkjedens hovedretning følger "Trondhjemsfeltets store synklinal".

Den ovenfor refererte diskusjon i Revolusjonshistorien blir også drøftet av HOLTEDAHL i "On the Caledonides of Norway", s. 26–27. Her antas at det VSV-lige foldesystem ikke bare er en senkaledonsk dannelse, men at det er et sekundært trekk som har sin årsak i at Syd-Norge på denne tid dannet en motstandsblokk, "along the border of which folds and overthrusts developed more locally, like breakers along a coast" (s. 26).

I Connections hevdet jeg videre at Kaledonidene fra Vestlandets devonsynklinalområde fortsetter i S-lig retning langs Vestlandet. For Haugesund-Stavanger området refererte jeg til HOLTEDAHLS "On the Caledonides of Norway", s. 22. HOLTEDAHL skriver:

"We must, however, be aware that the structural strike direction of the south-western coastal districts of Norway does not point southwestwards, but, in a number of curves, more or less N-S. To some extent the structure of the said districts has been determined by relatively late, post-Orcadian movements, but the N-S strike which predominates in the Haugesund-Stavanger district most probably is the result of the main Caledonian deformation processes".

Av sitatet fremgår at det bare er i den sydligste del av Vestlandet, i Haugesund-Stavanger området, at Holtedal antar at fjellkjedens hovedretning er N-S-lig.

Dette kan suppleres med et sitat fra HOLTEDAHLS Norges geologi, Bd. I, s. 443, øverst: "Flere forhold tyder på at sonen for den sterkere dypfoldning opprinnelig har forløpt omtrent N-S i strøket innenfor den sydlige del av de vestlandske kyststrøk og så svinget bueformet østover lenger nord". Her nevner Holtedahl, foruten den N-S-lige retning, en bueformet svingning østover, en svingning som må lokaliseres mellom Bergen og Haugesund.

Av ovenforstående diskusjon fremgår at det er en vesentlig forskjell i Holtedahls og mitt syn på Den kaledonske fjellkjedes hovedretning mellom Trondheim og Stavanger. Mens fjellkjeden etter Holtedahl får et tilnærmet rettlinjet forløp, regner jeg med en utpreget buet fjellkjede.

Da Holtedahls syn i store trekk synes å falle sammen med Vogts, og da Vogt gjennom årtier har arbeidet med disse problemer, og publisert sine resultater i en rekke avhandlinger, ledsaget av instruktive karter, fant jeg det naturlig i Connections m.h.t. tidligere litteratur i første rekke å referere til Vogt, og å diskutere hans synspunkter.

Jeg har ovenfor valgt å referere til OLAF HOLTEDAHL, både fordi STRAND nevner Holtedahl spesielt, i Summary og i selve artikkelen, og p.g.a. Holtedahls sentrale stilling i diskusjonen om Norges geologi.

I Connections diskuterte jeg Kaledonidenes lengderetning, før og etter Svalbardfasen, støttet av gamle, velkjente trekk i Norges geologi, og av nyere undersøkelser utført av Bergens- og Trondheimsgeologer. Som jeg også skriver i den innledende orientering: "In the following paragraphs I shall discuss features which throw light on the relationship between such an arcuate mountain range and the geology of Norway".

Etter å ha lest STRANDS manuskript sitter jeg igjen med det inntrykk at Strand stadig tenker på diskusjonen om hvorvidt Det vestlige gneisområde er "grunnfjell eller kaledonsk". I en slik diskusjon ville det selvsagt vært naturlig å referere både til Holtedahl og til eldre forskere. Men da jeg skrev Connections, fant jeg ingen grunn til ikke å gå ut fra som alminnelig kjent og antatt at Det vestlige gneisområde er mer eller mindre intenst kaledonsk påvirket.

En utpreget buet fjellkjede forutsetter naturligvis et kaledonsk gjennomarbeidet vestlig gneisområde. En tilnærmet rettlinjet fjellkjede forutsetter også etter min mening at Det vestlige gneisområde er kaledonsk preget; og i hvertfall er det ingen motsetning mellom en slik fjellkjede og et mere eller mindre intenst kaledonsk påvirket vestlig gneisområde. Så noen grunn til å komme inn på diskusjonen om Det vestlige gneisområdes alder i min diskusjon om fjellkjedens retning, kan jeg ikke se er tilstede.

At det er en markert forskjell mellom Trondheimsfeltet og Jotunheimsområdet fant jeg heller ingen grunn til ikke å gå ut fra som alminnelig kjent. Når jeg i den innledende orientering, etter å ha referert den sedvanlige tolkning av Kaledonidenes hovedretning, tilføyer at "On the other hand an essential difference has been claimed to exist between the Trondheim region and the Jotunheim region", var det for å markere diskusjonen om Jotunheimsområdets og Trondheimsfeltets stilling i Kaledonidene.

Men også Trondheimsfeltet er sedvanligvis antatt å være et forholdsvis perifert område av fjellkjeden. I et av de av STRAND siterte arbeider, skriver f.eks. HOLTEDAHL, etter å ha diskutert Jotunheimsområdet (1936, s. 137): "Også for eruptivmassene i Trondheimsfeltet må vi vel anta en lang, mer eller mindre horisontal transport, idet man i de masser som Trondheimsskifrene hviler på, ikke synes å finne gjennembruddsstrukturer".

De evt. variasjoner i Kaledonidenes hovedretning i følge denne diskusjon om Jotunheimsområdets og Trondheimsfeltets stilling i Kaledonidene, er dog som én retning å betrakte i forhold til min buete fjellkjede.

I et oversiktsarbeide, som Connections, vil det alltid være en vurderingssak i hvilken grad man skal referere tidligere forskeres resultater og synsmåter. Jeg la vekt på å referere VOGTS avhandlinger, som er av grunnleggende betydning for min idé om en utpreget buet kaledonsk fjellkjede.

Som jeg ovenfor ved hjelp av sitater har vist, synes HOLTEDAHLS syn i store trekk å falle sammen med Vogts. Jeg vil her fremheve at Vogts Revolusjonshistorie i år er 30 år gammel, og at HOLTEDAHL diskuterer denne. Jeg fant derfor ingen grunn til å komme nærmere inn på Holtedahls synsmåter.

Jeg har i dette svar, som ovenfor begrunnet, referert til Holtedahls produksjon. Men også de øvrige forskeres resultater er etter min mening tilbørlig referert i Connections.

Jeg kan derfor ikke se at jeg har unnlatt å referere avhandlinger av vesentlig interesse for mine idéer, men jeg beklager å ha skrevet på en sådan måte at et slikt inntrykk var mulig. Det være langt fra meg å ville undervurdere den store innsats som er gjort i utforskningen av vårt lands geologi, både av OLAF HOLTEDAHL og av andre forskere.

Jeg er enig i, og takker for den formelle kritikk.

Geologisk institutt, Universitetet i Bergen, januar 1958.

Ivar Hernes.

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Trykt August 1958.

En ny hypotese for de kaledonske kismalmers dannelse.

Autoreferat av foredrag i Norsk Geologisk Forening,
holdt torsdag 13. mars 1958.

AV

CHRISTOFFER OFTEDAHL

I 1873 publiserte Amund Helland den første større sammenstilling over våre kisforekomster. Den het «Forekomster av visse Kise i visse Skifere i Norge». I denne avhandling hevder Helland at kisene må være dannet sedimentært, da de har en rekke trekk som viser at de er et sediment slik som de skifre som de ligger i. Den samme antagelse hadde J. H. L. Vogt, som f. eks. uttrykt i et arbeid over Foldals kisfelt i 1889. Etter 1890 slo imidlertid Vogt om til magmatisk synspunkt. Han hevdet da og i senere arbeider at kisene er dannet i tilknytning til dannelsen av dyperuptiver, enten granitt eller gabbro. Først i 1919 kom det så noe nytt som brøt dette syn, idet C. W. Carstens hevdet at en viss kistype, den såkalte Leksdalstype, er dannet som et sediment på havbunnen og videre at kisen må stamme fra vulkanske ekshalasjoner. De andre, de store kisforekomster, hevdet imidlertid Carstens måtte være dannet magmatisk-metasomatisk, i arbeider fra 1932 og 1936. En oversikt over sine synspunkter har han gitt i 1944 og i sine malmgeologiske forelesninger av 1948 som foreligger stensilert. Det neste viktige arbeid som angår kisens dannelse kommer fra Harald Carstens, som i 1955 antar at Fosdalens jernmalmforekomst er dannet ekshalativt-sedimentært. Carstens finner nemlig at Fosdalsmalmen ligger i et større kompleks grønnskifre og nærmere bestemt i eller ved kvartskeratofyriske soner i grønnskifrene.

Mine egne undersøkelser i Grongfeltet begynte i 1952. Under arbeidet med kartbladene Tunnsjø og Trones ble jeg fortrolig både med bergartene og med en del av de mange små og store forekomster som ligger innen disse kartblad. Det viser seg da at vi i Grongfeltet har typiske vasskiser og tilsynelatende alle overganger fra vasskis til store kisforekomster. Videre finnes der også alle overganger fra typisk vasskis til sedimentære lag av magnetittmalm. Et viktig poeng er at malmene mer eller mindre er knyttet til lag av kvartskeratofyr. Disse ble av Foslie antatt å være intrusive granittiske bergarter, men jeg vil oppfatte dem som sure granittiske asker. Både vasskisene, overgangstypene og også noen av de store kisforekomster i Grongfeltet ligger nær knyttet til sure, pyroklastiske sedimenter, enten asker eller agglomerater. Dette kan lett sees for Skorovas og Gjersvikforekomstenes vedkommende, men er vanskeligere påviselig for Jomaforekomsten på grunn av overdekning.

Hvis vi går ut fra at de typiske vasskislag og blandingslagene av svovelkis og magnetitt er ekshalative sedimenter, blir det meget vanskelig å sette grensen mot de store forekomster. Hvor begynner de ikke-ekshalativ-sedimentære forekomster? Jeg tror, på grunn av den jevne overgang mellom vasskiser og store forekomster og den stadige tilknytning til de sure askelag, at alle kisforekomster stammer fra vulkanske utbrudd på havbunnen, knyttet til dannelsen av de granittiske asker. I nærheten av et slikt undersjøisk krater vil vi få utfelling av alle de tungmetaller som de vulkanske gasser inneholdt, vi får altså dannet en stor forekomst. Toverdig jern har den egenskap at det i surt havvann kan holde seg i oppløsning slik at store mengder jern kan transporteres i havstrømmer og felles ut i områder med høyere pH. Ved denne utfelling er det vesentlig jern som transporteres, og vi får da dannet, under reduserende forhold, de typiske vasskiser. Lokalt har vi hatt oksyderende forhold, og dette har gitt oksydasjon av jernet til oksyd, og vi har fått dannet magnetittlag.

Hvis vi så ser på en del av fjellkjedens øvrige sulfidiske malmer, skulle disse etter C. W. Carstens enten være knyttet til basiske eller til sure eruptiver, henholdsvis gabbroer eller trondhjemitter. Etter Foslie er imidlertid malmene i Ølve—Varaldsøystrøket i Hardanger mer eller mindre tydelig knyttet til utstrakte askehorisonter. Det samme er kjent å være tilfelle i Foldalsstrøket, idet den der kalte «gangart» ganske typisk er en regionalmetamorf albittbergart eller granittisk albittbergart med litt hornblende og granat. Også i Rørosstrøket kjennes slike lag, idet i alle fall noen av de såkalte «hardartslag» ganske typisk er albittrike bergarter, og om disse er vi nødt til å tro at de er sure asker. For øvrig vil jeg anta at den mer ubestemmelige «hardart» er blanding av sur albittrik aske og vanlig leirsediment eller basisk tuff. Videre nord, i Værdalsstrøket, er det meget tydelig hvordan malmen forekommer i forbindelse med kvartsporfyr, etter Gunnar Holmsen. Nord for Grongfeltet kommer vi til den Nordlandske sink-blyprovins. Her finner vi at Torgersen uttaler som en generell regel at sink- blymalmene forekommer som oftest knyttet til trondhjemittiske lag eller trondhjemittiske gneiser. Av kisforekomstene lenger nordpå skal jeg bare nevne Bjørkåsen, som etter detaljkartlegning av Foslie tydelig ligger i grønnskifer og i meget nær tilknytning til en langt utstrakt sone av kvartskeratofyr.

Det jern som gikk i oppløsning i havvannet og som ble transportert utover til nærliggende havstrøk, har gitt oss en ganske god datering av den malmgivende epoke i fjellkjeden. Det er nemlig blitt avsatt som oolittisk jern i Siljanstrøket i Mellom-Sverige og også i Oslofeltet[1]. Her er alderen «midt i 3 c», altså øverst i under-ordovicium.

Selve mekanismen for den ekshalativ-sedimentære dannelsesmåte for kismalmene som her er foreslått, blir altså delt i følgende trinn.

---

[1] Ifølge muntlig meddelelse fra dr. N. Spjeldnæs og cand. real. S. Skjeseth.

Først skjer det i et krystalliserende granittisk magma anrikning i gassfasen av tunge elementer, så strømmer gassen ut i havet og blir felt i havet, og til slutt vil vi under fjellkjededannelsen få en omkrystallisering av de i havet utfelte malmer. Angående det første punkt vet vi fra Oslofeltets kontaktforekomster at det særlig er rundt granittene at vi får dannet slike forekomster. Det er da tydelig at ved granittens krystallisasjon er det blitt dannet magmatiske gasser rike på følgende elementer: Jern, kobber, sink, bly, dertil mindre gehalter av arsen, antimon, vismut, kobolt, nikkel, og til slutt molybden og wolfram. Hvis slike gasser strømmet ut i et hav med reduserende forhold, ville gassene måtte felles som sulfider og gi nettop en forekomst av type Joma eller Skorovas. Hva angår selve felningsmekanismen, vil denne være avhengig av en rekke fysikalsk-kjemiske forhold i havet, i første rekke havets pH, havets gehalt av enten H_2S eller O_2, CO_2-husholdningen, og til slutt havstrømmene. Ved felning som sulfid i reduserende miljø vil den dannede sulfidgel sakte slå seg ned og havstrømmens transport ville da gi presipitatet en form som lange linjaler, nettop det som er det vanlige ved kisforekomster. Til slutt har så fjellkjededannelsens regionalmetamorfose omkrystallisert kisene og tektonisert deres grenser. Da kisene vil ha en helt annen kompetanse enn de omgivende bergarter, vil det svært ofte bli glidninger på grensene, som spesielt nevnt av Carl Bugge i 1948. De meget vekslende krystallisasjonsforhold vil så ha gitt kisene deres sterkt vekslende utseende fra primært båndete kiser til Sulitjelmas porfyroblastkis med svære svovelkisterninger.

Den her fremstilte hypotese for sulfidmalmenes dannelse er selvfølgelig ikke noe helt nytt. Lignende teorier er hevdet i 1948 av en tysk geolog F. Hegemann, og i 1957 har de tyske malmgeologer A. Cissarz og H. Borchert antatt at utstrakte sulfidmalmer i henholdvis Jugoslavia og Tyrkiet er dannet som ekshalativ-sedimentære forekomster. Men allerede gamle Helland var langt på vei i sitt arbeid av 1873, idet han til slutt i sine betraktninger om dannelsen påpeker at de ikke bare måtte være sedimentære, men også nevner at de sannsynligvis vil ha sitt jern og svovelinnhold fra vulkanske utstrømninger på havbunnen.

NY LITTERATUR

The Proterozoic in Canada. The Royal Society of Canada, Special Publications No. 2. Edited by JAMES E. GILL. University of Toronto Press 1957. Ca. 200 sider. Pris $ Canadisk 5.95.

Bergarter av antatt proterozoisk alder spiller i Canada en viktig økonomisk rolle med sine tildels verdensberømte forekomster av jern, kobber, sølv, platina, uran osv. Det økete kjennskap til såvel regional, som generell eksogen og endogen geologi har gjort det aktuelt å ta opp til revisjon hele problemkomplekset vedrørende gruppering av prekambriske bergarter. Noen god verdensomfattende inndeling av det tidsrum i hvilket de ble dannet (kanskje 5/6 av jordens historie) har man ikke. 23 geologer har levert bidrag til ovennevnte symposium, hvis formål er å klargjøre hvorvidt begrepet proterozoikum er berettiget, og hvis det er tilfelle, hvilke bergarter refererer seg til denne periode. Man får tydelig inntrykk av at bokens emne er aktuelt og at en revisjon var og fremdeles er nødvendig. Forfatterne som fritt har fått hevde sine egne synspunkter, er såvisst ikke enige. I de 19 artiklene som omhandler bestemte områder, kommer dette kanskje ikke så tydelig frem som i de resterende 5 artikler av helt generell karakter, hvor det gies oversikt over proterozoikum i Canada, livet i proterozoisk tid, grunnlaget for datering osv.

Inntil nå har man henregnet bergarter til proterozoicum i vesentlig grad på følgende grunnlag: fossilfunn (sparsomme og tvilsomme), bergarters petrografiske karakter (vesentlig shelf-type-sedimenter), metamorfose (lav), deformasjon (svak), diskordans mot arkeisk (høyere metamorft) underlag, intrusivkontakter etc. Absolutte aldersbestemmelser av bergarter bestemt som proterozoiske viser 500 til over 2000 millioner år. Et slikt tidsintervall vil omfatte flere orogeneser med bl.a omfattende granitisering. Overgrense for proterozoicum legges ved underkant av kambriums *Olenellus*-sone.

Det er spennende å følge de forskjellige forfatteres utvikling av synspunkter og deres kritikk av medforfattere. J. T. Wilson's sluttreplikk gir i grunnen mitt inntrykk av saken: In the present time of transition it is best to use local names. The subject of this symposium might have been made clearer if the title had been "Precambrian cover rocks in Canada".

Det er sjelden vi i norsk geologi snakker om proterozoicum. I overensstemmelse med de synspunkter som er fremlagt i dette symposium skulle det omfatte litt av den kambriske samt hele den Eokambriske lagrekke, videre Telemarksformasjonen, Trysilområdets porfyrer og sandstener (subjotnisk og jotnisk), Raipasformasjonen, Petsamontunturitt-formasjonen og, ja – man vet ikke hvor man skal slutte.

Universitetets Mineralogisk-Geologisk Museum, Oslo.

Johannes A. Dons

Prospektion von Uran- und Thoriumerzen. Av Dr. G. Zeschke. 76 + V sider. 26 bilder og 6 tabeller. E. Schweizerbart'sche Verlagsbuchhandlung (Nägele u. Obermiller). Stuttgart 1956.

Når det gjelder litteratur vedrørende uran- og thoriumprospektering har det i de senere årene dukket opp en del bøker, men få kan sies å gi en så god og kortfattet oversikt som dr. Zeschke's.

Det beste ved boken, er at den lar tingene få de rette proporsjoner. F.eks. blir det tydelig presisert at instrumentene bare er hjelpemidler som til og med sier svært lite om de ikke anvendes med forstand (og helst med en del geologisk innsikt). Og viktigst også for tolkningen av instrumentutslagene, er og blir en geologisk-mineralogisk undersøkelse. Dette gjelder både for uran og andre råstoffer, og bokens største avsnitt behandler således de geologiske forhold i forbindelse med uran-thoriumforekomster og behandlingen av uran-thorium mineralene.

Boken gir også en god oversikt over de metoder av mer teknisk og analyttisk art som i dag anvendes ved prospektering. Det er derimot ikke å vente at forfatteren i en så pass liten bok kan ha plass til å gå nærmere inn på vanskelighetene ved de enkelte analysemetodene. Det er jo et kjent forhold at mye tar seg lettere ut på papiret enn i virkeligheten. Boken er nok ment som en innføring i emnet, men det kan lett bli litt vanskelig for en uerfaren å vurdere viktigheten av de forskjellige metodene, deres begrensning og anvendelsesområder.

En stor fordel er den fyldige litteraturlisten, hvor mange geologiske-petrografiske og mineralogiske arbeider er nevnt, og en del artikler fra gruvetidsskrifter er tatt med.

Boken er skrevet så den med fordel kan leses av alle som har interesse for emnet, enten de er geologer eller bergfolk.

Men boken må også sies å gå videre, for selv om den først og fremst omhandler uran-thoriumprospektering, er den lagt opp etter så generelle prinsipper at de også kan anvendes ved planmessig prospektering etter andre malmer. Det er antagelig mange her i Norge som kunne ha interesse av og kanskje godt av å lese denne enkle boken, som en kort innføring i moderne malmleting.

Thor Siggerud.

NORSK GEOLOGISK FORENING

Møte nr. 371, 25. april 1957.

Til stede 25 medlemmer og 19 gjester.

Som nytt medlem ble innvalgt:

418. Universitetsstipendiat dr. philos. Ulf Hafsten, Botanisk Museum, Universitetet i Bergen.

Foredrag av Professor *Ivan Th. Rosenqvist:*

«De norske alunskifre og deres betong-agressivitet».

I ordskiftet etter foredraget deltok: N. Spjeldnæs, F. Øyen, T. Gjelsvik, H. Major, G. Holmsen, Sinding-Larsen, H. Rosendahl, I. Vogt-Nilsen og foredragsholderen.

Dr. Gunnar Holmsen satte fram forslag om at foreningen skulle ta opp arbeidet med å få utarbeidet et geologisk kart over Oslo by.

Møte nr. 372, 28. november 1957.

Til stede 15 medlemmer og 3 gjester.

Som nytt medlem ble innvalgt:

419. Mag. scient. Poul Graff-Petersen, Mineralogisk Museum, København.
Foreslått av H. Neumann og J. A. Dons.

Foredrag av mag. scient. *Henning Sørensen:*

«Ilimaussaqbatholiten — et sydgrønlandsk nefelinsyenitområde».

I ordskiftet etter foredraget deltok: Chr. Oftedahl, B. Dietrichson, O. Holtedahl, T. Gjelsvik og foredragsholderen.

Møte nr. 373 (julemøte) 12. desember 1957.

Til stede 37 medlemmer og 23 gjester.

Foredrag av geolog *Thore Winsnes:*

«Geologi og geologer på 80° nord».

Foredraget var ledsaget av fargefilm og fargelysbilder.

W. Werenskiold ytret seg etter foredraget.

Generalforsamling torsdag 6. februar 1958

i Drammensveien 78, Oslo

Årsmelding og regnskap for 1957 ble godkjent.

Reuschmedalje-komiteen 1957 hadde ikke funnet å kunne fremme noe forslag for tildeling av Reuschmedalje for 1957.

Valg:

Formann: *T. Strand.*
Viseformann: *N. Spjeldnæs.*
Sekretær: *F. Hagemann.*
Redaktør: *N.-H. Kolderup.*
Styremedlemmer: *K. Egede Larssen, A. Eriksen* og formennene i Bergens og Trondheims geologiske klubber.
Reuschmedaljekomite: *T. Gjelsvik, A. Kvale* og foreningens formann *T. Strand.*
Revisorer: *T. Gjelsvik* og *T. Winsnes.*
Sulitjelmafondet: *I. Oftedal, L. Størmer* med *I. Rosenqvist* som varamann.

A. Granli ble anmodet om å fortsette sin virksomhet som forretningsfører.

Årsmelding for 1957.

Siden siste generalforsamling er følgende medlemmer avgått ved døden:

Bergingeniør H. H. Smith
Rektor D. A. Danielsen

2 medlemmer er utmeldt av foreningen.

I samme tidsrom er innvalgt 5 nye medlemmer.

Foreningen har nå 242 medlemmer, derav:

2 korresponderende
119 livsvarige
121 årsbetalende.

Det er avholdt 5 ordinære møter med et samlet fremmøte av 177 personer.

Av Norsk Geologisk Tidsskrift er utkommet Bd. 37, h. 1—4.

Utdrag av regnskap for det ordinære budsjett for 1957

Inntekt

Beholdning, overført fra 1956: I kasse ...	kr. 853,80	
I bank ...	» 4 701,09	kr. 5 554,89
Innbetalt medlemskontingent		» 1 785,00
Tilskudd fra Staten		» 1 200,00
Tilskudd fra Norges Almenvitenskapelige forskningsråd		» 9 212,00
Ekstraordinært tilskudd fra Norges Almenvitenskapelige forskningsråd		» 14 796,00
Abonn. og salg av tidsskriftet....................		» 2 731,18
Renter av bankinnskudd		» 90,07
Renter fra livsvarige medlemmers fond		» 845,52
Renter fra Berg- og Steinindustriens fond		» 600,11
		kr. 36 814,77

Utgift

Tidsskriftet:		
Trykking Bind 36, hefte 3—4; 37, hefte 1 og 37, hefte 2.................................		kr. 22 486,00
Klisjeer Bind 36, hefte 3—4; 37, hefte 1 og 37, hefte 2.................................		» 6 306,00
Korrektur og tegnearbeide		» 897,00
Ekspedisjon av tidsskriftet		» 750,35
Arbeidshjelp, porto og skrivesaker.................		» 696,35
Møter og ekskursjoner		» 653,60
Representasjon, anskaffelser og Reuschmedaljen		» 445,66
Beholdning, overført til 1958: I kasse ...	kr. 1 105,45	
I bank ...	» 3 474,36	» 4 579,81
		kr. 36 814,77

Livsvarige medlemmers fond 1957.

1/1 1957.	Fondets kapital: .	kr. 18 110,00	Inntekt	Utgift
	Innbet. kontant i 1957:........	» 1 600,00		
		kr. 19 710,00		
	Herav i statsoblig. og aksjebrev.....	kr. 15 100,00		
	I bank	» 4 610,00		
31/12 57.	Urørlig kapital ...	kr. 19 710,00		
	Renter av verdipapirer for 1957		kr. 775,50	
	Renter av bankinnskudd for 1957		» 94,02	
	Forvaltning av verdipapirer			kr. 24,00
	Overført til ordinære budsjett			» 845,52
			kr. 869,52	kr. 869,52

Berg- og steinindustriens gavefond.

Fondets kapital .... kr. 20 000,00		
Renter av bankinnskudd	kr. 600,09	
Overført til ord. budsjett..............		kr. 600,09
	kr. 600,09	kr. 600,09

Regnskapet revidert av T. Gjelsvik og T. S. Winsnes: 15/1 1958.

Møte nr. 374, 6. februar 1958.

Til stede 42 medlemmer og 17 gjester.

Følgende innvalg ble godkjent:

420. Amanuensis Odd Gjems, Norges Landbrukshøgskole, Vollebekk.
Foreslått av J. Låg og S. Skjeseth.
421. Vitenskapelig assistent Georg Hamar, Institutt for geologi, Blindern.
Foreslått av L. Størmer og N. Spjeldnæs.
422. Cand. mag. Fredrik Chr. Wolff, Blindern Studenthjem, Oslo.
423. Cand. mag. Audun Hjelle, Institutt for Geologi, Blindern.
Foreslått av T. Strand og N. Spjeldnæs.

Foredrag av dr. *Gunnar Holmsen:*
«Litt av hvert om Norges geologiske undersøkelse gjennom 100 år».

Foredrag av direktør *Sven Føyn:*
«Den geologiske kartlegningen ved Norges geologiske undersøkelse».

Møte nr. 375, 13. mars 1958.

Til stede 36 medlemmer og 16 gjester.

Følgende innvalg ble godkjent:

424. Midlertidig statsgeolog Dwight F. Crowder, Norges geologiske undersøkelse.
Foreslått av: B. Bruun og Paul H. Reitan.
425. Siviling. Bjørn Bølviken, Statens Råstofflaboratorium, Trondheim.
426. Berging. Ivar Dybdahl, Hauge i Dalane.
Foreslått av J. A. W. Bugge, H. Carstens og R. Selmer-Olsen.
427. Vitenskapelig assistent Gerd Brevig Liestøl, Institutt for Geologi.
Foreslått av T. Strand og N. Spjeldnæs.

Det var fra professor Ivar Oftedal med tilslutning av professor Tom. Barth og dr. Henrich Neumann kommet forslag om å danne en mineralogisk gruppe innen Norsk Geologisk Forening. Den mineralogiske gruppe skal ha som sitt nærmeste formål å representere Norge i International Mineralogical Association, som for tiden er under dannelse.

Det ble etter forslag fra styret gjort følgende vedtak: «Norsk Geologisk Forening samtykker i at ovennevnte forslagsstillere og andre interesserte medlemmer danner en mineralogisk gruppe innen foreningen».

Opprettelsen av den mineralogiske gruppe forutsettes ikke å medføre økede utgifter for foreningen.

Foredrag av statsgeolog *Chr. Oftedahl:*

«En ny hypotese for de kaledonske kismalmers dannelse.»

I ordskiftet etter foredraget deltok: N. Spjeldnæs, I. Rosenqvist, H. Bjørlykke, L. Ormestad, B. Dietrichson, P. Holmsen, J. A. Dons, A. Rosenlund, T. Strand og foredragsholderen.

Bergens Geologiske Klubb.

Årsmelding for 1957.

Møte nr. 62, 4. mars.

Lektor *Isak Undås:* «Ra-morenen og Svelvikstadiet i Ryfylke og Sunnhordland.» 14 tilhørere.

Møte nr. 63, 7. oktober.

Dosent dr. *Tore Sund:* «Geologi og landskaper i Sør-Amerika. Inntrykk fra en reise.» 20 tilhørere.

Møte nr. 64, 20. november.

Førstekonservator dr. *Hans Holtedahl:* «Som geolog ved amerikanske havforskningsstasjoner.» 23 tilhørere.

Møte nr. 65, 2. desember.

Cand. mag. *Inge Bryhni:* «Tektonikk mellom Hornelen og Håsteinens devon.» 11 tilhørere.

Møte nr. 66, 16. desember (Julemøte).

Cand. real. *Markvard A. Sellevoll:* «Geologi og malmleting i Finnmark.» 40 tilhørere. Etter foredraget selskapelig samvær på Geologisk institutt.

Styret var i 1957:
Formann: Professor dr. Anders Kvale,
viseformann: Lektor Anders Samuelsen,
sekretær: Amanuensis Ivar Hernes.

PEGMATITE VEINS AND THE SURROUNDING ROCKS

II. Changes in the olivine gabbro surrounding three pegmatite veins, Risør, Norway.

BY

PAUL REITAN

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Abstract: A detailed study was made of the changes in the olivine gabbro surrounding three pegmatite veins at Risør, Norway.

The pegmatite veins and the surrounding rocks are briefly described petrographically. From the modal analyses of twenty samples the changes in the chemical composition of the surrounding rock as a function of distance from the veins were calculated. These calculations show that near each of the veins there exist zones of markedly increased basicity. A discussion of the distribution of pressure near a break in a competent rock (e. g. olivine gabbro) surrounded by a rock flowing plastically (e. g. gneiss) during the dynamic regional metamorphism leads to the conclusion that pressure differences would be created such that thermodynamic gradients would necessitate the migration of material from zones of relatively high pressure to zones of relatively low pressure, minerals of low mol volume being preferred in the zones of high pressure, while minerals of large mol volume would be preferentially formed in the zones of low pressure. The pegmatite veins and the nearby zones of increased basicity are therefore interpreted as the result of a process of metamorphic segregation during the dynamic metamorphism of the area.

Calculations of the density of cations per unit number of oxygen ions according to Barth's standard cell method (2, 3), and calculations of the changes in the volume occupied by a unit number of oxygen ions, based on a method taking into account the mol volumes and the modal percentages of the constituent minerals, verify the validity of the mode of formation proposed for the pegmatite veins and the nearby depleted zones of increased basicity.

Introduction

This paper is the result of a detailed investigation of the changes found in a normally very homogeneous country rock in the vicinity of three pegmatite veins. The country rock surrounding the veins is an olivine gabbro. In the near vicinity of the veins the surrounding rock is completely recrystallized and metamorphosed to amphibolite.

A series of samples was collected in a road cut in an olivine gabbro body near the town of Risør on the south coast of Norway. Figure 1 is a diagrammatic sketch of the road cut showing the relative positions of the veins and the locations of the samples.

The olivine gabbro occurs as an elongate body about 120 m wide and 1 km long before it disappears into the sea. It is surrounded by gneiss (gneissic migmatite and banded gneiss) and is elongate parallel to the main strike direction which, locally, is about N55E. The dips in this area are near perpendicular.

BUGGE'S (8) studies of the Kongsberg-Bamble formation and my detailed study of the island St. Hansholmen (23) indicate that the regional metamorphic facies reached in the Risør area was the amphibolite facies.

The gabbroic rocks which occur along the south coast of Norway have been very thoroughly studied and described by BRØGGER (7). The reader is referred to his paper for general information about these rocks, the variations in them, and their special characteristics. In this paper only those features which occur within the small area studied will be considered.

The paper is divided into two parts. The first part, in which interpretation has been avoided, is descriptive, presenting the data on which the second and interpretive part is based.

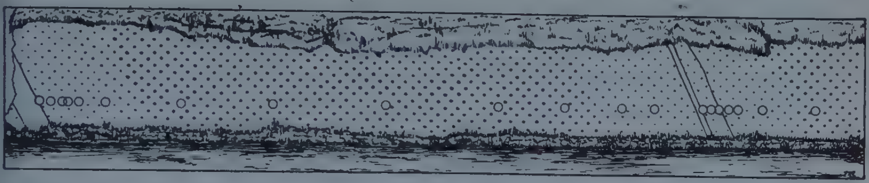

Fig. 1. Diagrammatic sketch of the roadcut from which samples were taken. The pegmatite veins are shown in white, the olivine gabbro is stippled, and the relative positions of the samples are shown by open circles. Vein number 1, at the left, is just over 1 meter broad. The horizontal distance between vein number 1 and vein number 2 is just over 25 meters. The sample farthest from the veins was taken at a point out of the sketch to the right, 15 m horizontally from vein number 2.

Petrography

PEGMATITE VEINS

The pegmatite veins consist primarily of plagioclase and quartz. A modal analysis was performed on an 80 cm² polished surface of vein number 1, the results of which appear in table 2. In vein number 1, the largest vein, there is an ill defined zoning; quartz and plagioclase being graphically intergrown near the boundaries and occuring as separate masses towards the center. Dark minerals are rare throughout; plates of biotite and very small flecks of opaque minerals having been seen. Vein number 2 also consists primarily of plagioclase and quartz, is slightly finer grained than vein number 1, is not visibly zoned, but contains a slightly higher percentage of dark minerals; biotite, hornblende, and garnet having been identified here. The two cm broad veinlet, vein number 3, is slightly finer grained than vein number 2, also consists primarily of plagioclase and quartz, with a small amount of hornblende and a very little biotite.

The An content of the plagioclase at three different points in vein number 1 was determined by means of the index of refraction. As can be seen from figure 2 the plagioclase in the vein is less calcic than that in the surrounding rock but becomes more calcic towards the center of the vein than it is near the vein boundaries. In figure 2 one can also see that the plagioclase of vein number 2 is less calcic than that of the surrounding rock.

OLIVINE GABBRO

The rock which surrounds the pegmatite veins consists of plagioclase, olivine, and clinopyroxene as essential minerals, apatite and and opaque minerals as accessories, and biotite, orthopyroxene, brown amphibole, and symplectitic green amphibole and spinel in corona structures (see table 2, sample R2PC9 for the modal analysis of the least metamorphosed sample). According to the system of classification proposed by JOHANNSEN (17) the rock receives the symbol 2312P; the appropriate petrographic name therefore being olivine gabbro.[1]

The micro-texture of the least metamorphosed olivine gabbro is medium grained, consisting of lath shaped plagioclase, equidimensional olivine, and sub-ophitic clinophyroxene. Coronas occur around the dark minerals. Biotite occurs in the coronas around the opaque minerals. A thin corona of brown amphibole occurs around clinopyroxene. Around the grains of olivine there occurs a double corona consisting of an inner corona of orthopyroxene and an outer corona of symplectitic light green amphibole needles[2] and dark green spinel blebs. These coronas are of types described by BRØGGER (7), SEDERHOLM (24), and others, and are in no way unusual.

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[1] Hyperite is the name which scandinavian geologists have generally used for the gabbroic bodies which occur in the Kongsberg-Bamle formation and for the similar bodies which occur in southwestern Sweden. BRØGGER (7), BUGGE (8), HØGBOM (14), TØRNEBOHM (25), and others have used the name hyperite. For reasons pointed out by GJELSVIK (12, pp. 116, 117) and from HJELMQUIST'S (13) review of the term hyperite, the author thinks that hyperite is an unnecessary petrographic term, and because of the difference in the meaning of the term, as defined by scandinavian geologists and by widely used petrography textbooks (HOLMES (15), JOHANNSEN (17), TRØGER (26)), it is a term subject to misunderstanding. Hyperite may be a useful geologic term if limited in application to those bodies of gabbroic rock occurring in southern Norway and southwestern Sweden. Used in this way the term includes normal gabbros, olivine gabbros, and gabbros transitional into norites. As this report is not a general report on the hyperites of the region but rather a report on the detailed changes in the rock within a very small area, the author prefers to use the petrographic term which accords with the world-wide petrographic nomenclature for the type of rock under consideration — that is, olivine gabbro.

[2] JØSANG (18) has identified diopside as the light green mineral in the outer corona around olivine from the Modum area. Therefore a tiny piece of the outer corona around olivine was separated and by means of an x-ray powder photo was identified as amphibole.

Within ca. 2.5 m of the pegmatite veins the olivine gabbro is completely recrystallized and metamorphosed to amphibolite. From the samples furthest removed from the veins to the zone of amphibolite nearest the veins, certain changes in the corona structures can be followed.

From the samples furthest removed from the pegmatite veins up to within about 4.5 m from the pegmatites the corronas increase in size. This is especially marked for the double coronas around olivine. Only the sample most distant from the veins contains appreciable amounts of olivine.

It appears to be the case that after the inner corona of orthopyroxene has, by growing inwards, completely replaced the original grain of olivine, the outer amphibole-spinel corona continues to grow at the expense of plagioclase and the inner corona of orthopyroxene until, at a distance of about 4.5 m from the veins, the orthopyroxene is completely replaced and only a cluster of small amphibole grains remains.

In the samples furthest removed from the veins the corona of brown amphibole around the ophitic clinopyroxene is quite thin. The corona becomes only slightly thicker upon approaching the veins until, quite abruptly within a small interval about 3.5 to 4.5 m from the veins, the clinopyroxene is completely replaced by amphibole.

At a distance of about 3 m from the veins there can therefore be seen two types of amphibole; the clusters of small grains derived from the original olivine and the large ophitic grains derived from clinopyroxene.

The coronas of biotite around the opaque grains are never very large and disappear completely when the rock becomes completely recrystallized.

Changes in the plagioclase can also be followed on approaching the veins. In the samples furthest removed from the veins the plagioclase occurs as lath shaped grains which are densely clouded by very fine inclusions. The inclusions impart to the plagioclase a quite dark brownish-violet color. Examination of a polished section in reflected light at 1000 times magnification revealed that the inclusions for the most part are approximately rectangular in shape and lie in the size range between 0.001 mm and 0.0001 mm. There were no detectable changes in the magnetic properties of the plagioclase with change in density of the inclusions insofar as this could be determined with the Franz Magnetic Separator. A quantitative spectrographic determination for Fe and Ti was performed on hand picked pure plagioclase from sample R1PC9, the results of which are shown in table 1. From the above information it seems most likely that the inclusions are primarily hematite. For other discussions on clouded plagioclase see Poldervaart and Gilkey (19) and Carstens (9).

Table 1.

Partial spectrographic analysis of clouded plagioclase.

Sample R1PC9		
Fe_2O_3 (total Fe)	= 0.25 wt. %	Analyst: B. Dirdal
TiO_2	= 0.05 « «	Sentralinstitutt for industriell forskning.

At a distance of about three meters from the veins the plagioclase occurs as corroded laths and the density of the inclusions is reduced. Within 2.5 m from the veins the plagioclase occurs as clear, unclouded, irregularly shaped grains.

Within 2.5 m distance from the veins the rock surrounding the veins is a completely recrystallized amphibolite. The amphibolite consists of medium sized, interlocking, irregularly shaped grains of plagioclase and green to greenish-brown amphibole with accessory apatite, opaque minerals, and biotite.

Besides the textural and qualitative mineralogical changes in the rock surrounding the pegmatite veins there are quantitative changes which are also clearly related to the veins.

There is a distinct variation in the composition of the plagioclase in the surrounding rock as a function of distance from the veins. This variation is shown in table 2 and diagrammatically, along with the change in composition of the plagioclase within vein number 1, in figure 2. The An content in the plagioclase from the various sample was determined by means of the index of refraction.

Spectrographic analyses of plagioclase for Sr showed that the Sr content in the plagioclase from the veins is lower than in the plagioclase from the sourrounding rock. Plagioclase taken near the boundary of vein number 1 contained ca. 100 ppm Sr while that taken near the center contained ca. 200 ppm. In the surrounding rock the Sr content

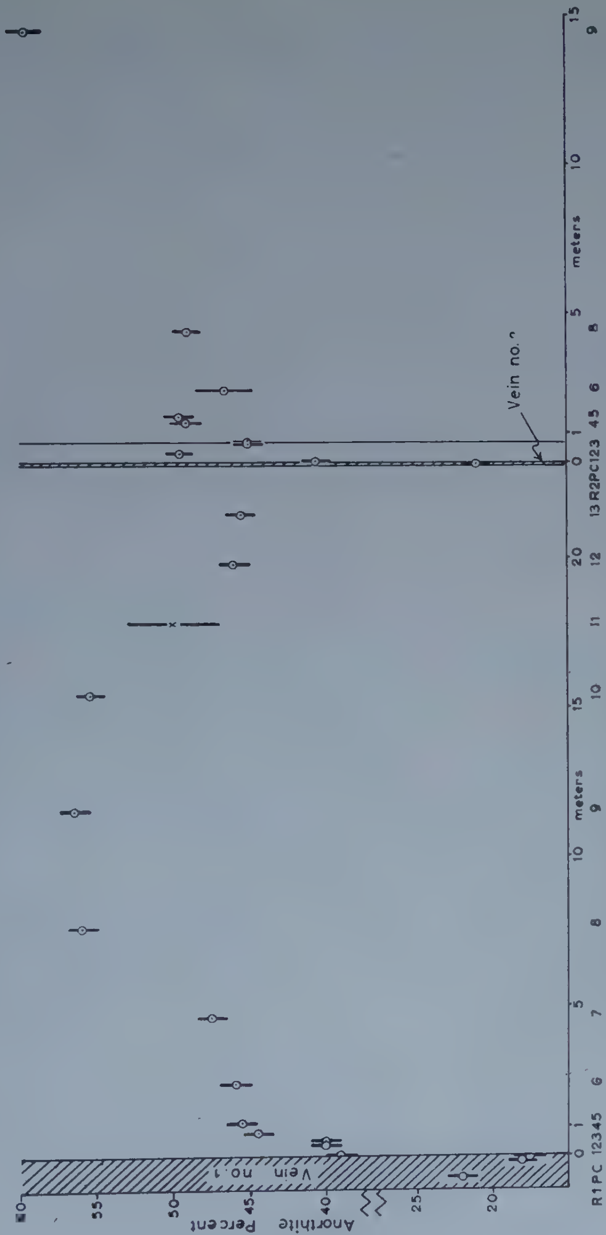

Fig. 2. The change of An content in the plagioclase shown as a function of distance. An content along the ordinate; distance along the abscissa.

in the plagioclase is quite constant at ca. 500 ppm except for samples R1PC4, R1PC5, R1PC13, R2PC2, and R2PC5 in which the Sr content is ca. 800 ppm. (Only one run was made of each sample and the amount of Sr was determined by visually estimating the relative density of the faintest step of the Sr line which could be seen on the spectrographic plate. Consequently no high degree of accuracy can be claimed for the figures given.)

Garnet occurs sporadically in tiny grains and in small clusters throughout the olivine gabbro. In one case it was observed as a participant in the outer corona around olivine. Garnet was separated from one sample (R1PC12) and its composition was determined from the unit cell size (11.514Å), index of refraction (1.775), and specific gravity (4.08). Its composition is therefore about 50 percent pyrope and 50 percent almandine. An x-ray powder diagram of garnet from pegmatite vein number 2 showed the same spacing as that of the garnet from the olivine gabbro.

Modal analyses were made of the thin sections of all the samples of the olivine gabbro except for sample R1PC2. This sample was omitted because the section was small and was dominated by three relatively large plagioclase grains. The thin section was evidently not representative of the rock at the point where the sample was taken. Modal analyses of 13 of the sections were made using the Hurlbut electric counter moving the slide at the rate of about 16 mm per minute. In those cases where the number of minerals to be counted exceeded the number of keys on the Hurlbut counter a point counter was used. 7 sections were counted with the point counter. The minimum number of counts was 1160 and the maximum was 1720. The results of the modal analyses are shown in table 2 and figures 3 and 4. In the diagrams showing the modal composition of the rocks the percentages of the various mineral types are plotted as a function of the distance from the veins.

As can be seen especially well from figures 3 and 4, there are quantitative mineralogical changes in the rock which surrounds the veins. It is to be noted that at a short distance from the veins there is a marked decrease in total plagioclase and a corresponding marked increase in total dark minerals. This change in the mineralogical composition is not strikingly evident in the field, partly, at least, being obscured by the change in color of the plagioclase.

Sample no.	Quartz	Plagioclase				Oli-vine	Clino-pyrox-ene	Ortho-pyrox-ene	Amphi-bole	Bio-tite	Garnet	Opa-que	Apa-tite	Σ Dark[2]
		An[1]	Total	Albite	Anor-thite									
R1PC1	—	39	65.4	39.9	25.5	—	—	—	28.7	0.7	3.2	1.7	0.3	31.9
3	—	40	56.2	33.8	22.5	—	—	—	37.1	5.8	—	0.4	0.4	37.1
4	—	44½[3]	44.7	24.8	19.9	—	—	—	52.6	0.1	—	2.2	0.3	52.6
5	—	46	47.1	25.4	21.7	—	—	—	49.9	2.1	—	0.8	0.1	49.9
6	—	46[3]	56.4	30.4	25.9	—	—	—	41.7	0.1	—	1.5	0.5	41.7
7	—	47½	62.6	32.9	29.7	1.9	6.1	9.4	18.5	—	—	1.3	0.2	35.9
8	—	56	62.1	27.3	34.8	—	1.2	9.7	17.5	1.2	6.5	1.8	—	34.9
9	—	56½	66.0	28.7	37.3	—	2.7	10.2	18.2	1.5	—	1.2	0.1	31.1
10	—	55½	61.3	27.3	34.3	—	0.9	11.6	24.1	—	—	1.8	0.3	36.6
11	—	50	61.8	30.9	30.9	1.0	11.6	5.3	16.6	—	—	3.5	0.2	34.5
12	—	46	37.7	20.4	17.6	—	—	7.4	43.5	—	10.0	1.0	0.3	60.9
13	—	45½	57.2	31.2	26.0	—	—	—	41.3	0.4	—	0.8	0.2	41.3
R2PC1	—	40½	39.2	23.3	15.9	—	—	—	43.3	16.6	—	0.6	0.2	43.3
2	—	49½	28.2	14.2	14.0	—	—	—	71.4	0.2	—	0.1	0.1	71.4
3	—	45	41.7	22.9	18.7	—	—	—	56.3	0.3	—	—	1.6	56.3
4	—	49	49.8	25.4	24.4	—	—	—	48.5	1.4	—	—	0.2	48.5
5	—	49½	27.5	13.9	13.6	—	—	—	72.1	0.1	—	0.3	0.1	72.1
6	—	46½	40.2	21.5	18.7	—	—	—	59.3	0.1	—	0.3	0.1	59.3
8	—	49	58.0	29.6	28.4	0.2	8.2	10.0	22.1	—	—	1.2	0.1	40.6
9	—	59½[3]	59.1	23.9	35.2	12.0	8.8	5.3	13.5	0.1	—	0.9	0.3	39.6
R1P1[4]	27.0	18	72.8	59.7	13.1	0.2								

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[1] An content of plagioclase determined by index of refraction except for R1PC11 for which the determination was by maximum-extinction angle in thin-section.

[2] The sum of olivine, pyroxenes, amphibole, and garnet.

[3] An content of plagioclase in these samples determined by the extinction angle in the plane ⊥ (001) and (010) and the maximum extinction angle in the zone ∥ (010) using the 5-axis universal stage, showed that the determination by refractive index was too high by 2 to 3 An %.

[4] Modal analysis of a sample from pegmatite vein no. 1; performed on a polished surface 80 cm².

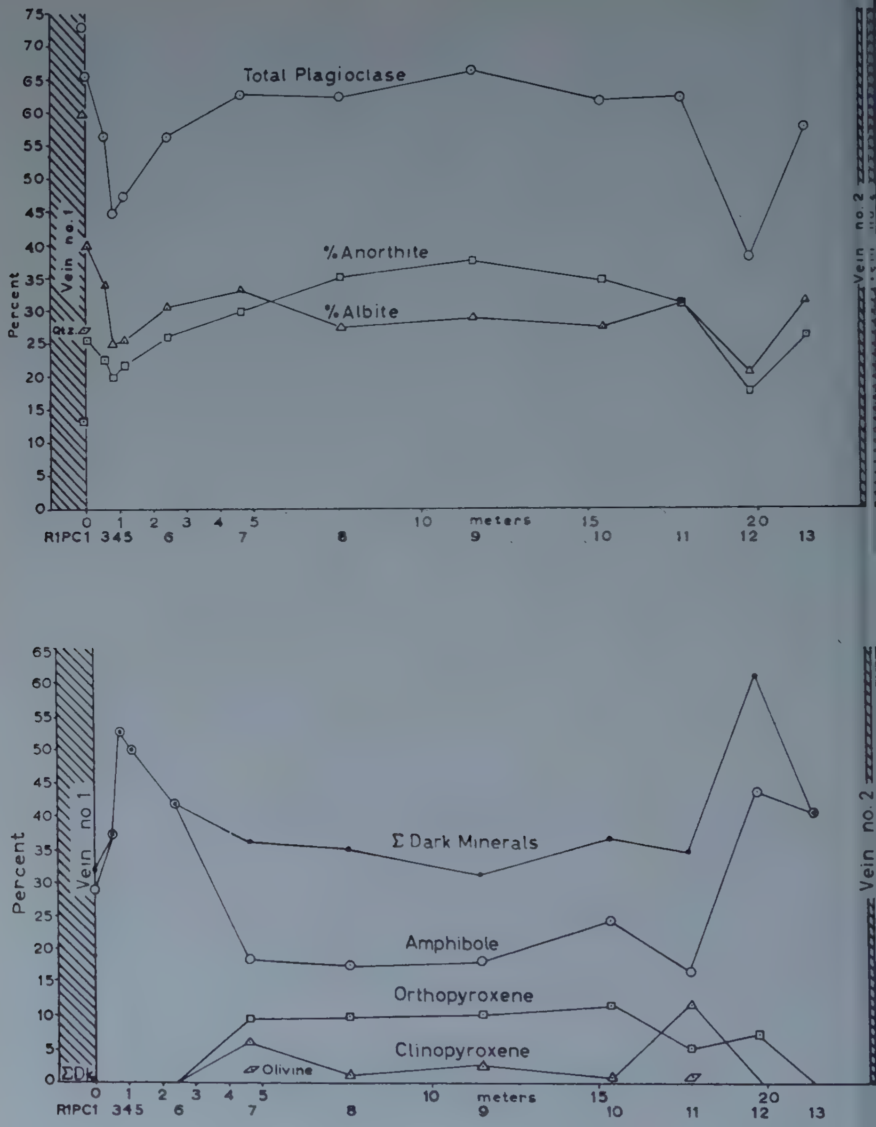

Fig. 3. Results of modal analyses. a. The variation in the percentage of plagioclase as a function of distance between vein number 1 and number 2. Total plagioclase is separated into anorthite and albite which is also shown. b. The variation of the dark minerals as function of distance between vein number 1 and number 2.

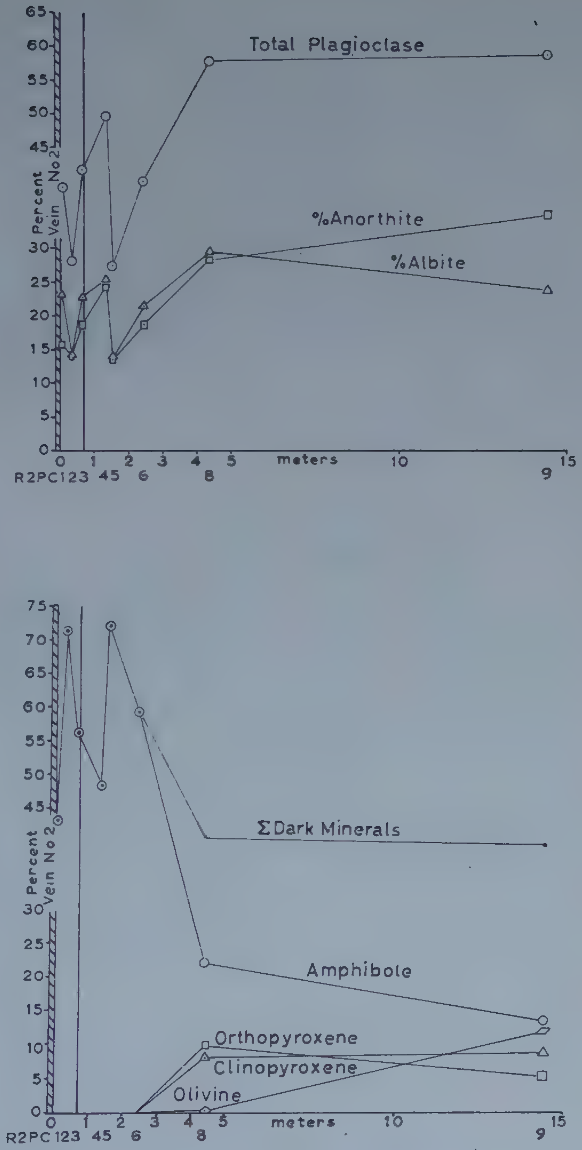

Fig. 4. Results of modal analyses. a. The variation in the percentage of total plagioclase, anorthite, and albite, as a function of distance from vein number 2. b. The variation of the dark minerals as function of distance from vein number 2.

The relationship between the curve for total dark minerals, amphibole, and plagioclase is interesting in that it supports the interpretation based on textural evidence that amphibole grows at the expense of plagioclase and the pyroxenes. It has been proposed (7) that this mineralogical reaction is possible with little or no change in the total chemistry of the rock.

Because this change may be possible without any change in bulk chemical composition and because the total content of the albite molecule in the rock (see figure 3) does not vary with the distance from the veins in the same way as the composition of the plagioclase varies (figure 2), interpretation and theorising concerning the genesis of the pegmatite veins on the basis of the data so far presented is hazardous. This is so because inspection of the data does not make the chemical changes in the rock evident.

Petrochemical calculations

Because a discussion of the genesis of the veins ought to take into consideration the changes in the chemistry of the rock surrounding the veins as a function of the distance from the veins, the chemical composition of the rock at the points where samples were taken was calculated from the modal analyses.

To do this the chemical compositions of the minerals had to be known. As mentioned previously, the composition of the plagioclase and the garnet was determined from physical properties. The composition of the amphibole could be determined with reasonable accuracy from the chemical analyses[1] of two samples of amphibolite. The remaining minerals occurred intimately intergrown in corona structures and were impossible to separate. Therefore the compositions of the individual mineral types could not be determined. However, by using the chemical analysis of the least metamorphosed olivine gabbro and subtracting the amounts necessary for plagioclase, amphibole, and accessories, the distribution of Si, Al, Fe, Mg, and Ca in olivine and the pyroxenes could be assumed. In addition a number of pub-

[1] Chemical analyses of three samples (R1PC4, R1PC6, and R2PC9) were performed in the analytical laboratory of the Geological Survey of Norway.

Table 3.

Mineral formulas used in petrochemical calculations[1]

Olivine	$Mg_6\ Fe_6\ Si_6\ O_{24}$
Orthopyroxene	$Mg_{4.9}\ Fe_{2.7}\ Al_{0.8}\ Si_{7.6}\ O_{24}$
Clinopyroxene	$Ca_{3.0}\ Mg_{3.0}\ Fe_{0.75}\ Al_{1.5}\ Si_{7.5}\ O_{24}$
Amphibole	$Na_{0.6}\ Ca_{1.8}\ Mg_{2.7}\ Fe_{1.35}\ Al_{2.3}\ Si_{6.7}\ O_{22}\ (OH)_2$
Biotite	$K_{1.8}\ Mg_{2.5}\ Fe_{2.5}\ Al_{3.0}\ Si_{5.8}\ O_{20}\ (OH)_4$
Garnet	$Mg_3\ Fe_3\ Al_4\ Si_6\ O_{24}$
Anorthite	$Ca_3\ Al_6\ Si_6\ O_{24}$
Albite	$Na_3\ Al_3\ Si_9\ O_{24}$

[1] Several of the formulas used do not agree exactly with the ideal formulas for the minerals. Real variations from ideality were taken into account.

Table 4.

Calculated compositions in cation %.

Sample	Si	Al	Fe	Mg	Ca	Na	K
R1PC1	49.1	23.9	3.2	5.8	8.6	9.3	
3	47.9	22.6	4.2	7.5	8.9	8.3	0.7
4[1]	46.9	21.3	4.7	9.4	10.4	7.2	
5	46.8	21.8	4.7	9.1	10.2	7.1	0.2
6[1]	47.6	23.1	3.7	7.4	10.2	7.9	
7	48.4	22.6	4.2	8.0	9.4	7.4	
8	46.8	24.9	4.7	7.8	9.4	6.2	0.1
9	47.4	24.8	3.7	7.2	10.2	6.5	0.2
10	47.5	23.8	4.2	8.0	10.0	6.5	
11	48.3	23.2	3.4	7.4	10.7	7.1	
12	45.9	20.7	7.0	11.9	8.7	5.8	
13	47.8	23.1	3.7	7.3	10.2	8.0	
R2PC1	45.7	20.9	6.5	10.3	8.3	6.4	1.9
2	45.3	19.2	6.3	12.5	11.2	5.6	
3	46.6	20.9	5.0	10.1	10.5	6.9	
4	46.7	22.4	4.5	8.7	10.6	7.0	0.2
5	45.2	19.0	6.3	12.6	11.2	5.6	
6	46.4	20.5	5.3	10.5	10.6	6.7	
8	48.2	22.2	4.1	8.7	10.0	6.9	
9[1]	45.7	22.2	6.5	9.7	10.3	5.5	

[1] The calculated values of Si, Al, Ca, and Na are slightly changed if the An %'s determined with the universal stage are used. Si changes by a maximum of 0.4 %, Al by a maximum of 0.7 %, Ca by a maximum of 0.5 %, and Na by a maximum of 0.3 %.

Table 5.

Chemical Analyses.

	R1PC4					R1PC6					R2PC9				
	Wt %	Cat-ion Prop.	Cat-ion %	Sub-tr.[1]) for acc.	Cat-ion[2]) % rec. to 100 %	Wt %	Cat-ion Prop.	Cat-ion %	Sub-tr.[1]) for acc.	Cat-ion[2]) % rec. to 100 %	Wt %	Cat-ion Prop.	Cat-ion %	Sub-tr.[1]) for acc.	Cat-ion[2]) % rec. to 100 %
SiO_2	47.66	7 943	44.41		46.53	48.15	8 025	44.95		47.15	47.83	7 972	43.87		45.16
TiO_2	1.84	230	1.28	1.28		1.32	165	0.92	0.92		1.00	125	0.69	0.69	
Al_2O_3	20.58	4 035	22.56		23.63	20.98	4 114	23.04		24.17	20.09	3 939	21.68		22.32
Fe_2O_3	1.02	128	0.72	0.72		1.51	189	1.06	1.06		0.67	84	0.46	0.46	
FeO	8.90	1 236	6.91	1.28 0.36	5.67	7.65	1 062	5.95	0.92 0.53	4.87	9.65	1 340	7.37	0.69 0.23	6.77
MnO	0.18	25	0.14			0.18	25	0.14			0.17	24	0.13		
MgO	5.45	1 362	7.62		7.98	5.13	1 282	7.18		7.53	7.85	1 963	10.80		11.12
CaO	9.25	1 652	9.24	0.28	9.39	9.00	1 607	9.00	0.40	9.02	8.80	1 571	8.64	0.27	8.62
Na_2O	3.60	1 161	6.49		6.80	3.83	1 235	6.92		7.26	3.29	1 061	5.84		6.01
K_2O	0.38	81	0.46	0.46		0.50	106	0.59	0.59		0.26	55	0.30	0.30	
H_2O-	0.10					0.90					0.11				
H_2O+	0.65					0.71					0.34				
CO_2	—					—					—				
P_2O_5	0.22	31	0.17	0.17		0.30	42	0.24	0.24		0.21	29	0.16	0.16	
S	0.28					0.60									
Total	100.11		100.00	4.55	100.00	99.95		100.00	4.66	100.00			100.00	2.80	100.00
O=S	0.07					0.14									
Total	100.04					99.81					100.27				

Analyst: Liv Bolkesjø, NGU Laboratory.

[1]) In order to make comparison with the calculated values possible, TiO_2, Fe_2O_3, P_2O_5 and the necessary FeO and CaO were subtracted, being attributable to accessory Ilmenite, Magnetite and Apatite.

Table 6.

Comparison between chemical analyses and calculated values.

Sample No.	Si	Al	Fe	Mg	Ca	Na
R1PC4[1] Chem. analysis	46.53	23.63	5.67	7.98	9.39	6.80
			13.65			
R1PC4 Calculated values	46.9	21.3	4.7	9.4	10.4	7.2
			14.1			
R1PC6 Chem. analysis	47.15	24.17	4.87	7.53	9.02	7.26
			12.40			
R1PC6 Calculated values	47.6	23.1	3.7	7.4	10.2	7.9
			11.1			
R2PC9 Chem. analysis	45.16	22.32	6.77	11.12	8.62	6.01
			17.89			
R2PC9 Calculated values	45.7	22.2	6.5	9.7	10.3	5.5
			16.2			

[1] The values given for the chemical analyses are in cation % recalculated to 100 % after subtraction of the cations which form accessory minerals. Accessories were not included in the calculated values.

lished analyses[2] of the minerals concerned were examined. The mineral formulas which were used in the calculations are shown in table 3.

The method used to make these calculations starts with the modal analyses and the formulas assigned to the minerals present. The calculation follows the reverse path of a norm calculation, stopping at the cation percent. Accessory minerals were ignored in the calculations.

The results of these calculations are shown in table 4 and diagrammatically in figure 5. The comparisons between the chemical analyses,

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[2] The chief sources were Howie (16), De Vore (10, 11), and Ramberg and De Vore (22). Analyses of 32 biotites, 30 hornblendes, 20 clinopyroxenes, 17 orthopyroxenes, and 2 olivines plus the study by Ramberg and De Vore (22) of co-existing olivines and orthopyroxenes were used to help in determining the mineral compositions to be used in the calculations.

Table 7. Modes calculated from chemical analyses expressed in cation percents.

	Si	Ti	Al	Fe+++	Fe++	Mn	Mg	Ca	Na	K	P	Modes Calc.	Modes Obs.
R1PC4	44.4	1.3	22.5	0.7	6.9	0.4	7.6	9.2	6.5	0.5	0.2		
Albite	15.6		5.2						4.7	0.5		26.0	24.8 (25.7)[1]
Anorthite	6.4		6.4					3.2				16.0	19.9 (19.0)[1]
Amphibole	22.4		10.9		5.3	0.4	7.6	5.7	1.8			54.1	52.6
Biotite	—		—		—		—			—		—	0.1
Opaque		1.3		0.7	1.6							3.6	2.2
Apatite								0.3			0.2	0.5	0.3
Yields Amphibole formula: $Na_{0.5}$ $Ca_{1.6}$ $Mg_{2.1}$ $Mn_{0.1}$ $Fe_{1.5}$ $Al_{3.1}$ $Si_{6.4}$ O_{22} $(OH)_2$													
R1PC6	45.0	0.9	23.0	1.1	5.9	0.1	7.2	9.0	6.9	0.6	0.2		
Albite	18.0		6.0						5.4	0.6		30.0	30.4 (31.8)[1]
Anorthite	7.4		7.4					3.7				18.5	25.9 (24.5)[1]
Amphibole	19.6		9.6		4.5	0.1	7.2	5.0	1.5			47.5	41.7
Biotite	—		—		—		—			—		—	0.1
Opaque		0.9		1.1	1.4							3.4	1.5
Apatite								0.3			0.2	0.5	0.5

R2PC9	43.9	0.7	21.7	0.5	7.4	0.1	10.8	8.6	5.8	0.3	0.2		
Albite	16.4		5.5						5.3	0.2		27.4	23.9 (26.6)[1]
Anorthite	11.3		11.4					5.7				28.4	35.2 (32.5)[1]
Olivine	4.0				4.0		4.1					12.1	12.0
Clinopyroxene	3.7		1.5		0.4		1.8	1.4				8.8	8.8
Orthopyroxene	3.4		0.5		0.8		2.8					7.5	5.3
Amphibole	5.1		2.8		1.2	0.1	2.1	1.2	0.5	0.1		13.1	13.5
Biotite	—		—		—		—			—		—	0.1
Opaque		0.7		0.5	1.0							2.2	0.9
Apatite								0.3			0.2	0.5	0.3

Yields Olivine formula: $Mg_{6.0}\ Fe_{6.0}\ Si_{6.0}\ O_{24}$
Clinopyroxene « : $Ca_{2.5}\ Mg_{3.2}\ Fe_{0.7}\ Al_{2.7}\ Si_{6.8}\ O_{24}$
Orthopyroxene « : $Mg_{5.9}\ Fe_{1.7}\ Al_{1.1}\ Si_{7.4}\ O_{24}$
Amphibole « : $K_{0.1}\ Na_{0.6}\ Ca_{1.5}\ Mg_{2.5}\ Mn_{0.1}\ Fe_{1.5}\ Al_{3.3}\ Si_{6.1}\ O_{22}\ (OH)_2$

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[1] The values shown in parentheses are those obtained if the An values determined by use of the universal stage are used.

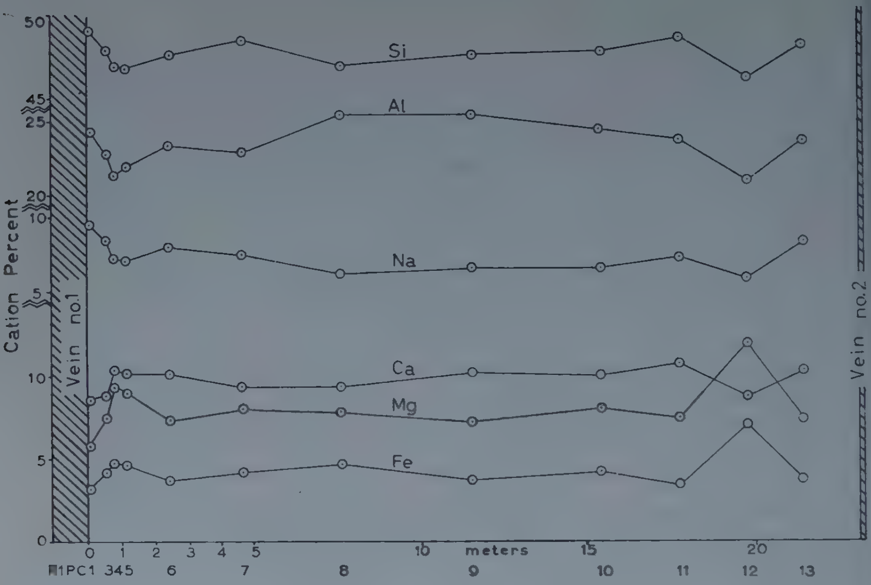

Fig. 5 a. Results of the calculated chemical compositions as a function of distance between vein number 1 and vein number 2.

shown in table 5, (recalculated to cation percents and again recalculated to 100 percent after the subtraction of TiO_2, Fe_2O_3, P_2O_5, and the necessary FeO and CaO to form the accessories) and the calculated compositions are shown in table 6. From the chemical analyses the modes were also calculated in the manner shown by BARTH (5) (see table 7).

On the diagram showing the variations in the calculated composition of the rock surrounding the veins the reader is asked to note especially the shape of the curves for Si, Al, and Na in contrast to the curves for Mg, Fe, and Ca. Strikingly borne out by these curves is the fact that near the veins there exists a zone of markedly increased basicity of the surrounding rock. It is clear that those elements which are enriched in the veins are depleted in the basified zones near the veins, while those elements which occur in only minimal amounts in the veins are enriched in the nearby zones. Ca follows the curves of Mg and Fe more closely than those of Si, Al, and Na, but occupies an

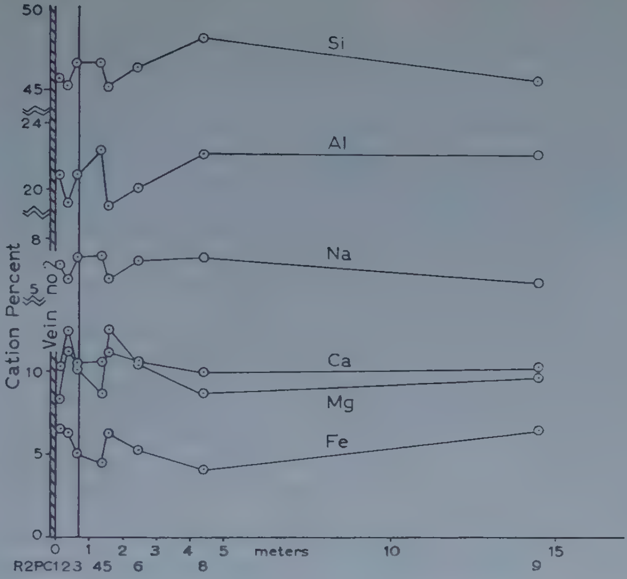

Fig. 5 b. Results of the calculated chemical compositions as a function of distance from vein number 2.

intermediate position. This is not surprising as Ca occurs in appreciable amounts both in the plagioclase and in the dark minerals, hornblende and clinopyroxene.

Having come this far it seems that one has enough data to begin the discussion of the genesis of the pegmatite veins.

Genesis of the Pegmatites

The explanation of the zones of increased basicity, their location near the pegmatite veins, and the cause of the formation of the pegmatite veins, is to be found in the physical properties of the rocks and the resulting distribution of pressure in them during the dynamic metamorphism of the area.

The olivine gabbro is surrounded by gneiss which deformed plastically during the dynamic metamorphism of the area (8, 23). The olivine gabbro must be reckoned as a very competent rock which would

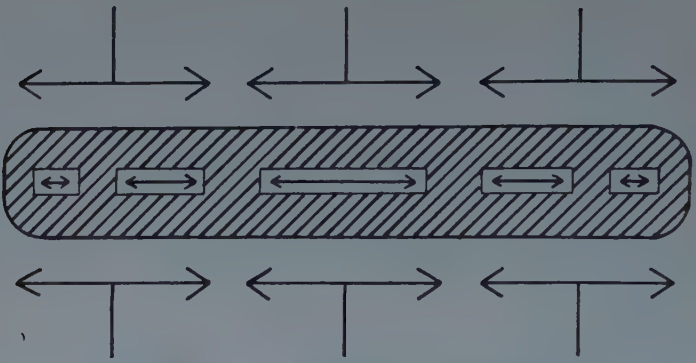

Fig. 6. A boudin in which the arrows show the magnitude of the tensile stress caused by the plastic flow of the surrounding gneiss.

be capable of only very little plastic deformation (see ANDERSEN, 1 and RAMBERG, 21).

In order to understand what happens within the competent olivine gabbro in response to the plastic deformation of the surrounding gneiss, let us first consider the distribution of tensile stress within a boudin surrounded by plastically flowing gneiss, the whole being under compression.

The friction along the surface between the competent boudin and the plastically flowing gneiss which surrounds it gives rise to tensile stress within the boudin. The tensile stress at any point within the boudin will be a function of the distance of that point from the nearest end of the boudin, such that the tension increases as the distance from the end increases (see figure 6 and RAMBERG, 21, figure 2, p. 516). If the boudin is not capable of sufficient plastic deformation it will break when the tensile stress becomes sufficiently great. In a homogeneous boudin the break must occur near the middle of the boudin — not at the ends where the tension is least. Any zone of weakness will, of course, be a favorable site for fracture if it is in a part of the boudin which is under sufficient tensile stress.

What is seen to be the case within the boudin is applicable to the olivine gabbro body. It is a very competent and homogeneous body surrounded by gneiss which flowed plastically.

Within the part of the olivine gabbro under consideration one can assume that at first quite uniformly distributed tensile stress was developed. At a zone of weakness (due e. g. to slight inhomogeniety or previous tectonic disturbance) there occurred a break (which would be essentially perpendicular to the direction of tensile stress) in which the pressure would be exceptionally low, and across which the tensile stress could not be transmitted. After the break has occurred its sides are directly comparable to the ends of the boudin, except that the pressure in the break would be less than the pressure in the plastic gneiss which surrounded the boudin. (It is most unlikely that the gneiss would have flowed plastically into the break where the pegmatite vein now exists. The roadcut from which the samples were taken is fully 40 m from the nearest gneiss. The largest vein is only 1 m broad. The break was undoubtedly much less than 1 m across when it was first formed and therefore the viscosity of the gneiss would have been too great to allow it to flow into the break. See p. 304 for further discussion of the development of the break.) The tensile stress in the olivine gabbro, caused by the plastic flow of the surrounding gneiss, will therefore be at a minimum adjacent to the break and will increase as the distance from the break increases (figure 7, b).

As the tensile stress can be thought of as tending to pull the mineral grains apart from one another in the direction of the stress, thus reducing the pressure on the grains in that direction, it follows that the minerals grains in the olivine gabbro are under anisotropic pressure (see figure 7, a and b) because of the tensile stress caused by the plastic flow of the surrounding gneiss. The degree of anisotropy of the pressure at any point will be directly proportional to the tensile stress at that point. Therefore, as the tensile stress caused by the plastic flow of the gneiss increases with distance from the break, the anisotropy of pressure due to this effect will increase with distance from the break (figure 7, c). However, there is another factor which, near the break, will cause anisotropic pressure on the grains.

In the break the pressure is exceptionally low. Because the pressure in the break is very low the mineral grains in the olivine gabbro immediately adjacent to the break will be under strongly anisotropic pressure (low pressure in the direction perpendicular to the break). This effect will decrease with increasing distance from the break (figure 7, d). The effect on the mineral grains is similar to that due to the tensile stress caused by the plastic flow of the gneiss, but its change of magnitude relative to the distance from the break is oppo-

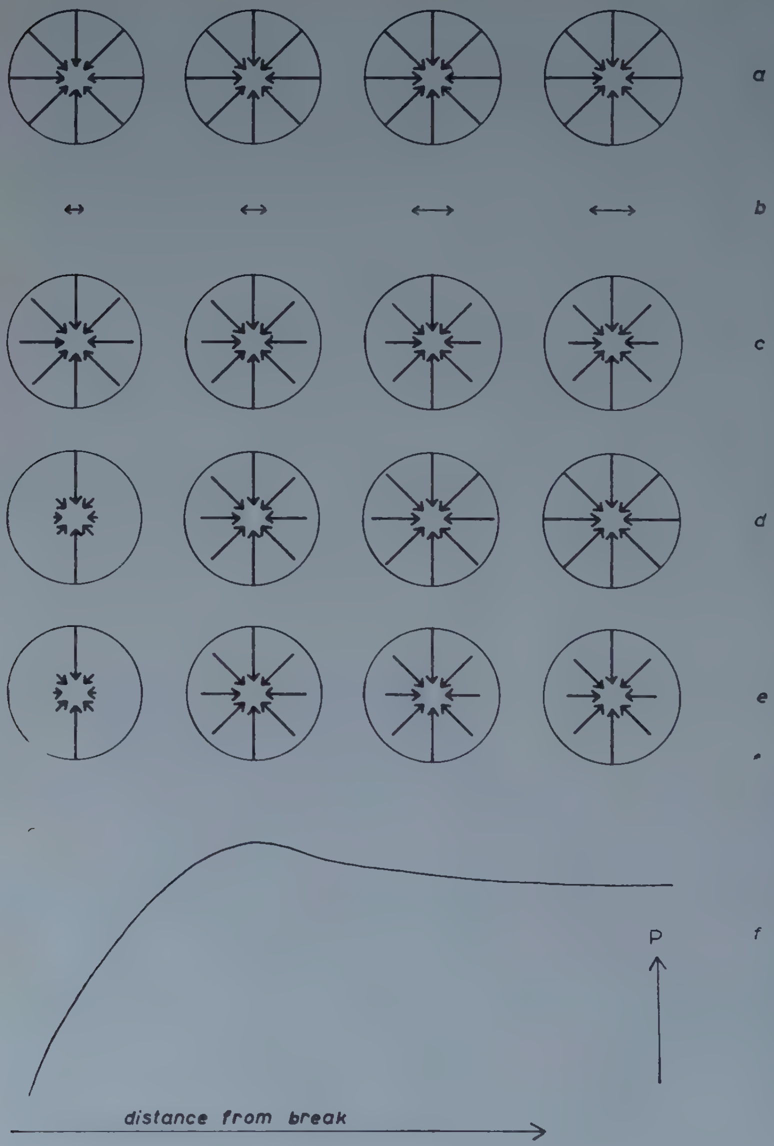

Fig. 7. In the diagram the break is at the left hand side. Distance from the break increases towards the right.

site. That is to say, the reduction of pressure in the direction perpendicular to the break because of the tensile stress caused by the plastic flow of the gneiss will be directly proportional to the distance from the break, whereas the reduction of pressure in the direction perpendicular to the break because of the very low pressure in the break will be inversely proportional to the distance from the break.

If these two effects are superimposed one is able to draw pressure rosettes for several points in the olivine gabbro showing the relative amount by which the pressure in the direction perpendicular to the break is reduced (figure 7, e). The curve showing the variation of pressure (in the direction perpendicular to the break) with distance from the break which results from this superimposition is shown in figure 7,f. The exact shape of this curve will depend on the competence of the rock in which the break occurs. A more competent rock would be able to support a steeper pressure gradient adjacent to the break. The effect of differences in the competence of the rock in which a break occurs is shown in figure 8. Only in a competent rock could one expect a marked pressure maximum to have been maintained.

The development of the distribution of pressure postulated above causes a thermodynamically unstable situation. From a system previously under homogeneous pressure a system with low pressure

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Fig. 7. Continued.

a. Pressure rosette for isotropic pressure due to hydrostatic pressure before deformation begins. Arrows represent the direction and magnitude of the pressure.

b. The arrows show the variation in magnitude of the tensile stress (due to the plastic flow of the gneiss) with distance from the break.

c. Pressure rosettes showing the change in anisotropy of pressure (due to the plastic flow of the gneiss) with distance from the break. Note that the reduction in pressure in the direction perpendicular to the break is *directly* proportional to the distance from the break.

d. Pressure rosettes showing the change in anisotropy of pressure (due to the very low pressure in the break) with distance from the break. Note that the reduction in pressure in the direction perpendicular to the break is *inversely* proportional to the distance from the break.

e. Pressure rosettes showing the change in anisotropy of pressure when the two effects which cause reduction in pressure in the direction perpendicular to the break are superimposed.

f. Curve showing the change in pressure in the direction perpendicular to the break with distance from the break.

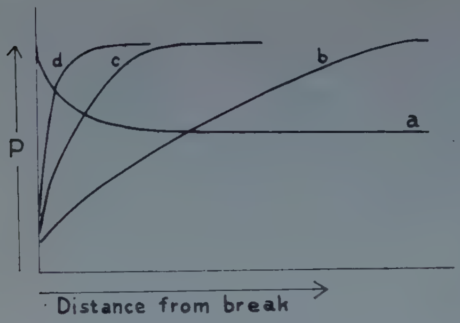

Fig. 8. Pressure curves in the direction perpendicular to the break. Curve a. shows the pressure in this direction caused by the plastic flow of the gneiss. Curves b., c., and d. show possible pressure gradients adjacent to the low pressure in the break for increasingly competent rocks. In very competent rocks a pressure maximum occurs near the break, being nearer the break the more competent the rock

zones and varying stress has been created. The result will be that the system will shift in such a way as to neutralize the effect of this change (the principle of Le Châtelier).

The creation of a low pressure zone in the break gives rise to mechanical pressure gradients (figure 7, d) which cause chemical activity gradients such that the material in the area of relatively high pressure (where the activity is high) will migrate towards the zone of low pressure (where the activity is lower). That the activity gradients parallel the pressure gradients is shown by the following equations which state the relationship between pressure, P, free energy, F, and the activity, a:

$$\left(\frac{\partial F}{\partial P}\right)_{T,X} = V$$

where V is the molal volume and T, the absolute temperature, and X, the bulk chemical composition of the system, are kept constant, and

$$F_i = RT\ln a_i + F_i^o$$

where R is the gas constant, the subscript i indicates the chemical species i, and F_i^o is the free energy in the standard state.

The activity gradients necessitate the transport of material into the low pressure zone. Consequently the minerals in the higher pressure areas will begin to disintegrate and the constituents will migrate towards the low pressure zone where new minerals will form from the disperse phase which is introduced. Those minerals which will be most favored in the low pressure zone are minerals of high mol volume

(e. g., feldspar and quartz). On the other hand, minerals of low mol volume (e. g., amphiboles and pyroxenes) — those which most efficiently concentrate cations — will be favored in the area of higher pressure. This transport of material tends to equalize the pressure differences by reducing the amount of material in the areas of high pressure, thereby relieving the pressure, while increasing the amount of material in the low pressure zone. (For other and more detailed discussions of this process the reader is referred to Barth, 4, pp. 317, 318, and Ramberg, 20, pp. 215—220.)

This process leads primarily to the formation of feldspars (plagioclase if the environment is poor in K) and quartz in the zone of low pressure, the exact composition of the newly crystallized mineral assemblage being dependent on the composition of the disperse phase from which the minerals grew. The surrounding rock is depleted in the constituents which predominate in the newly crystallized minerals, i. e., primarily Si, Al, and Na.

From the discussion of the distribution of pressure in the olivine gabbro in the vicinity of the break it was seen that the anisotropy of the pressure on the mineral grains varied with distance in the direction perpendicular to the break. The stress on the minerals will, of course, cause recrystallization in order to relieve the stress, as indicated by Riecke's principle. However, it is to be remembered that at a short distance from the veins there exists a zone of maximum pressure in the direction perpendicular to the veins in which the anisotropy of pressure is least. In this zone the tendency for the constituents in the disperse phase to crystallize in local low pressure zones adjacent to the stressed grains is less than in any other part of the olivine gabbro, because the local pressure differences are less. However, the pressure difference between this zone and the low pressure zone in the break is greater than the difference between any other part of the olivine gabbro and the break. Therefore, it is from this zone of relatively little anisotropy of pressure that the greatest percentage of the material in the newly crystallized mineral assemblage in the break will be derived. This zone will suffer the maximum depletion of those constituents which are enriched in the low pressure zone, Si, Al, and Na, and the maximum relative enrichment of the remaining constituents, Mg, Fe, and Ca.

The deformation of the olivine gabbro caused by the plastic flow of the gneiss is continuous throughout a period of time. The break slowly but steadily opens and is equally steadily filled by the crystallization of new minerals. The pressure differences are relieved by recrystallization (according to Riecke's principle) and by the loss of material to the low pressure zone, but are simultaneously constantly built up anew by the steady deformation. Consequently the degree of depletion in the relatively high pressure zone in the olivine gabbro can be considerable, the extent of the depletion being a function of the length of time of the deformation. The process of transfer of material will stop as soon as the pressure differences have been equalized after the deformation stops. Because the process is a response to the deformation one can expect to see no distortion adjacent to the low or the high pressure areas.

A discussion of this process which is in many respects similar to the one above, though with reference to a somewhat larger scale and with more exhaustive thermodynamic justification, has been published by Bennington (6).

The proposals above seem to constitute the most satisfactory explanation for the genesis of the pegmatite veins and the nearby zones of markedly increased basicity. Any explanation, whether it be magmatic, hydrothermal, or metasomatic, which requires that the material now present in the pegmatite veins was introduced exclusively from outside of the olivine gabbro body is unable to explain the changes in the chemistry of the rock surrounding the veins. Yet the regular repetition of the zones of increased basicity near the veins requires that both these zones and the veins be explained by one and the same process.

Two calculations have been made which serve to support the suggestions made above.

Assuming that the composition of the sample R1PC9 (taken approximately midway between veins number 1 and number 2) represents essentially unaltered olivine gabbro one can, by means of Barth's standard cell calculation (2, 3), determine the changes in the cations per 160 oxygen ions which occur during the rearrangement of material proposed above. The change in going from R1PC9 to the average of R1PC4 and R1PC5 (samples taken from the zone of increased basicity near vein number 1) and the change in going from R1PC9 to R1PC1 (the sample nearest vein number 1) were calculated. The results are

Table 8.

Standard Cell Calculations.

<table>
<tr><th>Sample No.</th><th>Si</th><th>Al</th><th>Fe</th><th>Mg</th><th>Ca</th><th>Na (+K)</th><th>Total</th></tr>
<tr><td>R1PC9
Cations per 160 O</td><td>48.3</td><td>25.3</td><td>3.8</td><td>7.3</td><td>10.4</td><td>6.8</td><td>101.9</td></tr>
<tr><td>R1PC1
Cations per 160 O</td><td>50.1</td><td>24.4</td><td>3.2</td><td>5.9</td><td>8.8</td><td>9.5</td><td>101.9</td></tr>
<tr><td>R1PC4
Cations per 160 O</td><td>48.8</td><td>22.2</td><td>4.9</td><td>9.8</td><td>10.8</td><td>7.5</td><td>104.0</td></tr>
<tr><td>R1PC5
Cations per 160 O</td><td>48.6</td><td>22.7</td><td>4.9</td><td>9.5</td><td>10.7</td><td>7.6</td><td>104.0</td></tr>
<tr><td>Average
R1PC4 & R1PC5</td><td>48.7</td><td>22.4</td><td>4.9</td><td>9.7</td><td>10.7</td><td>7.6</td><td>104.0</td></tr>
<tr><td rowspan="2">R1PC9
to R1PC1</td><td rowspan="2">+1.8</td><td rowspan="2">−0.9</td><td colspan="2">−2.0</td><td rowspan="2">−1.6</td><td rowspan="2">+2.7</td><td rowspan="2"></td></tr>
<tr><td>−0.6</td><td>−1.4</td></tr>
<tr><td rowspan="2">% change
R1PC9 to R1PC1</td><td rowspan="2">+3.6</td><td rowspan="2">−3.6</td><td colspan="2">−18.0</td><td rowspan="2">−15.1</td><td rowspan="2">+25.3</td><td rowspan="2"></td></tr>
<tr><td>−14.7</td><td>−19.7</td></tr>
<tr><td rowspan="2">R1PC9 to
Av. R1PC4 & 5</td><td rowspan="2">+0.4</td><td rowspan="2">−2.9</td><td colspan="2">+3.5</td><td rowspan="2">+0.3</td><td rowspan="2">+0.8</td><td rowspan="2"></td></tr>
<tr><td>+1.1</td><td>+2.4</td></tr>
<tr><td rowspan="2">% change R1PC9
to Av. R1PC4 & 5</td><td rowspan="2">+0.8</td><td rowspan="2">−11.2</td><td colspan="2">+31.0</td><td rowspan="2">+3.0</td><td rowspan="2">+10.4</td><td rowspan="2"></td></tr>
<tr><td>+29.1</td><td>+31.9</td></tr>
</table>

Changes R1PC9 to R1PC1		Changes R1PC9 to Av. R1PC4 & R1PC5	
Adding	Subtracting	Adding	Subtracting
1.8 ions Si 2.7 ions Na(K)	0.9 ions Al 0.6 ions Fe 1.4 ions Mg 1.6 ions Ca	0.4 ions Si 1.1 ions Fe 2.4 ions Mg 0.3 ions Ca 0.8 ions Na(K)	2.9 ions Al
4.5 ions representing 9.9 valences	4.5 ions representing 9.9 valences	5.0 ions representing 10.0 valences	2.9 ions representing 8.7 valences

Table 9.

Example of volume change calculation.

Mineral	Modal %	Recalculated to 100 %	Mol volume	Volume number
Albite	28.7	29.6	301	8909.6
Anorthite	37.3	38.4	302	11596.8
Clinopyroxene	2.7	2.8	242	677.6
Orthopyroxene	10.2	10.5	259	2719.5
Amphibole	18.2	18.7	278	5198.6
				29102.1

Calculated volume changes.

% Change R1PC9 to Av. of R1PC4 and R1PC5 = −0.75
% « R1PC9 « R1PC1 = +0.31
% « R1PC9 « R1P1 = +0.69

shown in table 8. These calculations show that in the zone of increased basicity there is an increase in the total number of cations per 160 oxygen ions which is especially marked for Mg and Fe. However, this calculation assumes that the volume occupied by 160 oxygen ions remains constant and that the volume of rock in a given area remains essentially unchanged. That is, the method is designed to enable one to calculate the cation changes which take place during volume for volume replacement. But this is not what has been proposed above. It has been proposed that the volume (e. g., occupied by a given number of oxygen ions, for the sake of a reference standard) in the zone of increased basicity has been reduced. If this is so, then the increase in Mg and Fe per unit volume is even greater than that indicated by the «standard cell» calculation.

Consequently, a calculation was made which would show the change in volume of a fixed number of oxygen ions.

The mineral formulas presented earlier (table 3, p. 291) are all based on 24 oxygen ions per formula. This was taken as defining one mol of each mineral. The mol volumes of the various minerals concerned were then calculated. Then the modal percentages of the main minerals in samples R1PC9, R1PC5, R1PC4, R1PC1, and R1P1 (from pegmatite vein number 1) were recalculated to 100 % and these figures were multiplied by the appropriate mol volumes. This yielded a number which is proportional to the volume occupied by the specific mineral in the sample concerned. The sum of these numbers for each sample gives a number proportional to the volume of 100 mols of the rock — the volume of rock containing the standard number of oxygen ions. A sample calculation (for R1PC9) is given in table 9. The percent changes in going from R1PC9 to the average of R1PC4 and R1PC5, to R1PC1, and to R1P1 are also shown in table 9.

These calculations verify the validity of the proposal that the zones of increased basicity are residual zones in which Mg and Fe have been relatively enriched while the volume occupied by the remaining rock has decreased. Simultaneously the volume of the rock adjacent to the veins and the rock now occupying the veins is greater than the original volume of the olivine gabbro. That the sum of the two volume increases is greater than the volume decrease is attributable to two factors. First, immediately after the break occurred there would be a certain amount of elastic recoil in the olivine gabbro such that the break would consist of an unfilled volume available to filling by high volume minerals without necessitating an exactly corresponding volume decrease in the olivine gabbro. Second, while the vein grows the two parts of the olivine gabbro are bodily moved apart from one another due to the plastic flow of the gneiss, such that the present system, vein plus surrounding rock, occupies a greater volume than did the olivine gabbro before the break occurred.

It may be suggested that the presence of hydrated minerals (primarily amphibole) in (roughly) decreasing quantity with increasing distance from the veins, indicates that the material now forming the veins was derived from a fluid rich phase which was introduced into the break in the olivine gabbro from some external source. The author does not believe this to be the case.

As is so elegantly explained by Ramberg:

«The opening will first be filled with the most mobile constituents of the host rock, that is, water, carbon dioxide, and other «fugitive» and mobile compounds existing throughout the rock. We concluded . . . that the pressure in these gaseous fillings in the begining would not exceed the total vapor pressure of the rock's minerals with their intergranular adsorbed particles. . . . Such a hydrous liquid phase would also, in most cases, have a pressure less than the rock pressure.

> After the first rather rapid filling of the opening with the most fugitive constituents, there will still be disequilibrium in the rock-fissure system because minerals existing in the fluid filled fissure have still less molal free energy than the correponding minerals in the rock. . . . The tendency will necessarily be that minerals slowly disintegrate in the rock and the constituents diffuse towards the low-pressure place, where precipitation must take place. . . .
>
> The growth of minerals along the wall of the crack and the plastic yield of the host rock make the fluid-filled volume of the opening decrease, followed by an increase of pressure of the fluid phase. If the wall was impermeable . . . , the pressure in the filling would gradually become equal to the pressure in the rock, and the situation would be mechanically stable. Since the walls are permeable, however, the fugitive constituents will start to diffuse from the fluid filling into the country rock, whereas the elements constituting the minerals in the fissure may continue to migrate into the fissure until the process comes to a stop when the fissure is closed either by plastic yield in the country rock and/or by the newly formed minerals.» (20, pp. 215, 216).

Some of the data concerning placioclase are also easily explained on the basis of the mode of formation of the pegmatite veins suggested above.

The observations which must be explained are: the variation in the An content from the boundary towards the center of vein number 1; the abrupt change of the An content in the plagioclase on crossing from the veins into the surrounding rock; the gradual increase of the An content in the plagioclase with distance from the veins; the variation of Sr content in the plagioclase from the veins; and the variation of the Sr content in the plagioclase in the surrounding rock.

It has been shown how the creation of the pressure differences postulated requires the diffusion of material in the disperse phase towards the low pressure zones. It is probable that Na is much more mobile and diffuses more rapidly than Ca, but even if one does not accept this as probable, it is the case that the recrystallization of the olivine gabbro would require the local use and retention of Ca for the formation of the low mol volume minerals which are relatively preferred. Therefore, in the disperse phase which migrates towards the low pressure zones, Ca will lag behind and/or will be preferentially retained. Consequently, the disperse phase will become richer in Na on approaching the veins and, just after the break opens, be much richer in Na than was the mineral assemblage from which it was derived. Therefore, the plagioclase which grows in the break will grow from a relatively Na rich environment. The plagioclase which recrystallizes in the surrounding rock will also be in a more Na rich environment the closer it is to the vein, but here the sites of disintegration and recrystallization are so close that the environment will be richer in Ca throughout the surrounding rock than it is in the vein.

The environment in the break will become gradually enriched in Ca through time because the slower moving Ca catches up to the Na which reached and crystallized in the break first and/or because the environment in the surrounding rock becomes effectively satiated with respect to Ca and will no longer preferentially retain it. Therefore, the plagioclase growing in the vein will become steadily richer in Ca. The last formed plagioclase (in the center of the vein) must then be richer in Ca than that which formed first.

The variation of Sr in the plagioclase both in the veins and in the surrounding rock is rather similar to that of Ca, except that Sr is markedly increased in the zones of increased basicity. This would indicate that Sr is even less mobile than Ca and or preferentially retained even more strongly than Ca. Consequently the variations of the Sr content are similar to but more pronounced than those of the Ca content in the plagioclase.

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Errata

In Pegmatite Veins and the Surrounding Rocks: I. Petrography and Structure: Norsk Geologisk Tidsskrift, Bind 36, Hefte 3, pp. 213—239, 1956, the following corrections should be made.

p. 213 (Abstract) — for An_{30} read An_{20}
— for An_{23} read An_{28}
p. 231 — for 244 cm^3 read 234 cm^3
— for 244,000 cm^3 read 234,000 cm^3

Attached map — the scale is given as 1 : 600. Because the map was reduced less than was anticipated when it was reproduced the scale is actually almost 1 : 400.

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FUNN AV BOREALE FURUSTAMMER FRA ODDERNES I VEST-AGDER

PÅVISNING AV TAPES-TRANSGRESJONEN

Boreal pine trunks from Oddernes (Vest-Agder, Norway). Demonstration of the Tapes-transgression

Av

ULF HAFSTEN

Abstract. A number of sub-fossil pine trunks were found about 3 m below surface at Oddernes School, just north of Kristiansand, in the southernmost coastal part of Norway (Fig. 1). The stems were embedded in the lowermost part of a c. 1.2 m thick layer of highly humified peat and were extraordinarily well preserved. The peat was overlain by a c. 2.15 m thick layer of clay mud, which contained marine indicators: *Ruppia*, "*Hystrix*" and *Discorbina*. No marine indicators were recognized in the compact sand layer below the peat.

The trend of pollen curves is very characteristic. Therefore, the diagram from Oddernes could easily be zoned in accordance with my two other diagrams from this district, viz. Fluetjern in Oddernes and Cladiumtjern in Søgne (HAFSTEN 1956, Pl. 16). The sudden immigration of alder and the first advance of mixed oak-forest indicates the zone border V—VI (Boreal/Atlantic) at about 2.15 m below surface. The high NAP-percentages in zone V is due to the local vegetation on the bog surface. NAP disappears when the bog complex was flooded by the sea (by the Tapes transgression) at the end of Boreal time. The boundary between Zones VI and VII has been fixed at c. 1.35 m, at the level of immigration of lime and the considerable advance of oak. Because of the decrease of elm, the zone-border VII—VIII (between Atlantic and Sub-Boreal time) has tentatively been defined at c. 0.15 m below surface. The relatively frequent occurrence of pollen of *Hedera*, *Viscum* and spores of *Osmunda* from 1.60 m below surface to the top confirms that this part of the diagram really corresponds with the post-glacial warmth period. The finding of another four pollen grains of *Ephedra distachya* type from this region (cp. the AP-diagram) is of special palaeobotanical significance, as these pollen grains, particularly the two uppermost ones, date from a period when the mixed oak-

forest grew rather densely in this region. Since 1956, when I published the first records of subfossil *Ephedra* pollen grains from Norway, a number of new finds have been made, and now it cannot be questioned that this strange shrub really was a constituent of the late-glacial and also of the early postglacial vegetation of southern Norway. The dry hills, as well as the precipices of the uneven area just north of the plains and terraces of Kristiansand and the southernmost part of Oddernes (e. g. Preståsen) undoubtedly provided useful refuges for heliophilous and xerophilous plants like *Ephedra*, even in Atlantic time, when the mixed oak-forest grew densely enough between the hills and the cliffs.

Since the boundary between Zones V and VI is very sharp and well-defined, the pine stems can with a great degree of reliability be dated to the Boreal period, and most probably to the first part of it, i. e. nearly 9000 years ago.

The characteristic stratigraphical sequence, a thick clay mud layer deposited on top of the terrestric peat layer, as well as the interchange between fresh-water indicators (*Potamogeton*, *Menyanthes* and *Pediastrum*) on one side and marine indicators (*Ruppia*, *Hystrix* and *Discorbina*) and sea-shore plants (*Elymus arenarius*, *Plantago maritima* and pollen of *Chenopodiaceae*) on the other, depicts a typical transgression phase. According to the zonation of the diagram there can be no doubt that this phase refers to the Tapes-transgression, which is known from a series of southern and southwestern coast stations situated on the outskirts of the last glaciation. The thickness of the clay mud layer shows that this transgression must have been at least 2 m at this place and that the shore-line before that time lay below c. 7.35 m.

Funnforhold

Under utgraving av byggetomt på Oddernes skole like ved Kristiansand i 1956 støtte grunnarbeiderne på en rekke meget vel bevarte furustammer. Stammene lå i ca. 3 m dyp under terrengoverflaten, dels direkte på det underliggende sand- og gruslaget, dels i den nedre delen av et ca. 1,2 m tykt, kompakt torvlag. Torvlaget var igjen dekket av et vel 2 m tykt lag med leirgytje (se stratigrafikolonnen lengst til venstre i pollendiagrammet, pl. 1). Det var Håkon Nakling, den gang skolebestyrer ved Oddernes skole, som innså den vitenskapelige betydningen av dette eiendommelige funnet. Han sendte stammesnitt av en av de groveste furustammene til Universitetet i Oslo. Denne stammen, som målte hele 50 cm i tverrmål, hadde fremdeles barken sittende på. Gjennom professor O. A. Høeg fikk så Botanisk Museum, Universitetet i Bergen, melding om funnet. Og da jeg nettopp hadde påbegynt en pollenanalytisk utforskning av Sør-

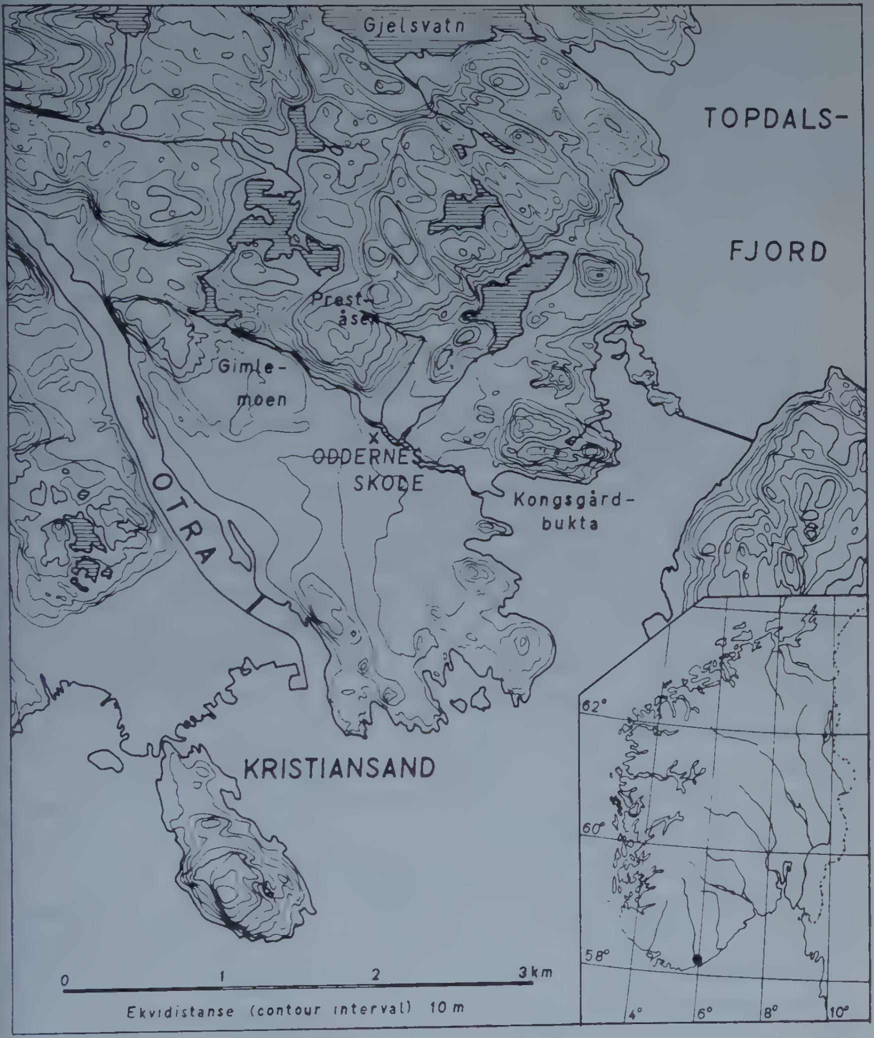

Fig. 1. Utsnitt av Topografisk kart over Kristiansand Omland, blad II Otra.

landet, overlot professor K. Fægri, styreren for Botanisk Museum, til meg å foreta nærmere undersøkelser i forbindelse med funnet. Jeg anmodet derfor Nakling om å ta ut en prøveserie fra disse lagene og sendte ham samtidig en detaljert beskrivelse av hvorledes han skulle gå frem. Han var så elskverdig å etterkomme denne oppfordringen, og ca. 1. juli 1956 fikk jeg sendende 36 prøver som var tatt med 10 cm mellomrom, fra overflaten og ned i det underliggende sandlaget. Jeg står i dyp takknemlighetsgjeld til Nakling for hans initiativ i forbindelse med dette funnet. Dessuten gir jeg ham min uforbeholdne kompliment for den omhyggelige måten han har tatt ut prøvene på. Ikke en eneste prøve viste nemlig tegn på forurensning under prøvetagningen.

Laboratoriearbeid

Analysearbeidet ble utført på Botanisk Museum i løpet av februar måned 1958. Det er utført vesentlig etter de prinsipper som er angitt av Fægri & Iversen 1950. Prøvene fra furumyrtorven — laget fra bunnen og opp til 215 cm under overflaten — er behandlet etter Erdtman's modifiserte acetyleringsmetode. Men prøvene fra leirgytjen — laget fra 215 cm og opp til overflaten — måtte også flussyrebehandles. Bortsett fra de to prøvene fra det underliggende sandlaget, var oppbevaringstilstanden for pollenet gjennomgående meget god. Disse prøvene var lite egnet for kvantitativ analyse og er derfor blitt utelatt i diagrammet. Men det faktum at også sandlaget inneholder små mengder med pollen av hassel (*Corylus*), viser at torvdannelsen først begynte i boreal tid.

Pollendiagrammet

Resultatet av analysene er fremstilt i et sammensatt pollendiagram som er konstruert vesentlig etter de samme retningslinjer som diagrammene i min Oslo-avhandling (Hafsten 1956). — Etter dybdeskalaen og stratigrafikolonnen lengst til venstre følger først AP-diagrammet, et sammensatt treslags-pollendiagram. Dette viser prosentforholdet mellom pollenmengdene av de forskjellige treslag og busker. Det er her ikke tatt hensyn til at de forskjellige trær og busker har forskjellig pollenproduksjon (sml. Fægri & Iversen 1950 s. 86). I virkeligheten har de treslagene som inngår i ekblandskogen — alm, lind, eik og ask — langt mindre pollenproduksjon enn furu, bjerk, or og hassel. Hvis man vil forsøke å omsette resultatet av analysene i aktuell vegetasjon, må man være oppmerksom på dette forholdet.

Standarden for beregningsgrunnlaget er minst 500 treslagspollenkorn pr. prøve. For prøvene fra leirgytjelaget ligger beregningsgrunnlaget oftest på over 1000 treslagspollenkorn. Dette kommer av at pollensummen for urter ellers ville blitt for liten.

Dernest følger QM-diagrammet, et spesialdiagram for ekblandskogskonstituentene — alm, lind, eik og ask — i 4 ganger så stor målestokk. Ekblandskogen representerer nemlig det varmekjære skogselementet her til lands. Det innbyrdes forholdet mellom de forskjellige ekblandskogskonstituentene er derfor av avgjørende betydning såvel for soneinndelingen som bedømmelsen av klimautviklingen.

Det tredje partialdiagrammet, TOTAL-diagrammet, er et oversiktsdiagram som viser prosentforholdet mellom mengden av treslagspollenet (AP) på den ene siden (svart silhuett) og pollenet av vindbestøvende urter og lyng (NAP) på den annen (skravert silhuett). Dette diagrammet er først og fremst viktig for vurderingen av skogdekkets tetthet. Men som vi senere skal se, er TOTAL-diagrammet i dette tilfelle også av betydning når det gjelder å forstå vekslingene i havstanden på dette stedet. Beregningsgrunnlaget er her lik summen av AP pluss NAP.

Det siste partialdiagrammet, NAP-diagrammet eller feltsjiktdiagrammet, viser det innbyrdes prosentforhold mellom pollenmengdene av vindbestøvende urter og lyng (*Ericales*). Når pollenet av mjødurt (*Filipendula*), som jo nærmest er en insektsbestøver, også er inkludert, skyldes det at denne planten i virkeligheten har en usedvanlig stor pollenproduksjon. Pollenet av marimjelle (*Melampyrum*) derimot, er beregnet utenpå NAP-summen, nærmere bestemt av summen av NAP pluss *Melampyrum*. NAP-diagrammet er basert på et beregningsgrunnlag på minst 100 pollenkorn. I leirgytjelaget forekommer urtepollen så sparsomt at jeg her har måttet slå sammen to og to prøver for å få et beregningsgrunnlag på 100, som er det minste man kan tillate seg å basere en prosentberegning på.

En del pollentyper forekommer for sparsomt til at de kan fremstilles ved egne pollenkurver. Prosenttallene for disse er derfor enten angitt i kolonner i de partialdiagram hvor de hører hjemme, eller skrevet inn der det er plass i diagrammene. Dette gjelder selje og vier (*Salix*), osp (*Populus*), krossved (*Viburnum*) og gran (*Picea*) i AP-diagrammet, strandrug (*Elymus*), strandkjempe (*Plantago maritima*), melde (*Chenopodium*), syre (*Rumex*), malurt (*Artemisia*), mjødurt (*Filipendula*) og marimjelle (*Melampyrum*) i NAP-diagrammet. I de nederste 60 cm forekommer likevel de to sistnevnte urter så rikelig at de er blitt fremstilt ved egne kurver. Da misteltein (*Viscum*), bergflette (*Hedera*), kongsbregne (*Osmunda*) og halvgresset storåk (*Cladium mariscus*) er viktige klimaindikatorer, er forekomsten av disse blitt angitt i QM-diagrammet. De to sistnevnte arter hører jo egentlig hjemme i feltsjiktet.

Forekomsten av ferskvannsplantene bukkeblad (*Menyanthes*) og tjønnaks (*Potamogeton*), saltvannsplanten havgras (*Ruppia*), samt de marine indikatorene «*Hystrix*» og *Discorbina*, er anført til høyre i diagrammet. *Menyanthes*, *Potamogeton* og *Ruppia* er prosentberegnet utenpå summen av treslag, urter og vannplanter. *Discorbina* og *Hystrix* derimot, er angitt med et pluss eller et uendelighetstegn alt ettersom det forekommer under eller over 12 pr. analyse.

Soneinndelingen som er angitt helt til høyre i diagrammet, følger Jessen's 9-delte system. Pollensonene parallelliseres med Blytt-Sernanders klimaperioder på følgende måte:

Sone V — boreal tid
- VI—VII — atlantisk -
- VIII — subboreal -

Da jeg stadig har bruk for å henvise til mitt Oslo-arbeide, skal det bemerkes at jeg i senere arbeider har forandret sonebetegnelsene for boreal og atlantisk tid, slik at sone V—VI (boreal), VIIa og VIIb (atlantikum) i HAFSTEN 1956 er ekvivalent med henholdsvis sone V (boreal), VI og VII (atlantikum).

Soneinndeling

Kurveforløpet i Oddernes-diagrammet er usedvanlig markert og stemmer for det meste godt overens med de to pollendiagrammene jeg allerede tidligere har publisert fra Kristiansand-traktene: Fluetjernet i Oddernes, ca. 7 km VNV for Oddernes skole, og «Cladiumtjernet» i Søgne (HAFSTEN 1956 pl. 16). Oddernes-diagrammet har også mange trekk felles med de diagrammene som er under utarbeidelse fra Lista.

Sone V — boreal tid: De høye verdiene for hassel og furu, den ubetydelige forekomsten av ekblandskog og den totale mangelen på or, gjør at den nedre delen av diagrammet, opp til ca. 215 cm under overflaten, uten tvil må henføres til sone V eller boreal tid. Særlig er det boreale hassel-maksimum vel utviklet og når 260 cm under overflaten en verdi på hele 47 %. Omkring 215 cm under overflaten skjer det imidlertid dyptgripende forandringer i diagrammet: Orekurven etablerer seg meget raskt, ekblandskogen (alm og eik) gjør et plutselig sprang fra under 2 til over 7,5 %, furukurven faller fra 52,5 til 22,5 % og hasselkurven, som allerede gjennom flere prøver har vært på jevn retur, er her i ferd med å synke under 20 prosent-linjen. Det er nettopp disse trekk som er karakteristiske for sonegrensen V—VI, og det kan derfor ikke være tvil om at denne grensen må trekkes omkring 215 cm under overflaten.

Det at urtepollenet spiller en så dominerende rolle i forhold til treslagspollenet (se TOTAL-diagrammet) er ikke noe vanlig trekk for pollensone V, men må i dette tilfelle utvilsomt tilskrives rent spesielle forhold. Vanligvis forekommer slike høye urte-prosenter bare i de eldste avsnittene av senkvartær tid, da skogdekket ennå var usammenhengende og temmelig glissent. Men i og med at furu og hassel for alvor rykker frem, på overgangen fra preboreal til boreal tid, blir skogdekket vesentlig tettere. I pollendiagrammene gir dette seg utslag i en markert nedgang for urtepollenet (sml. f. eks. Fluetjern og «Cladiumtjern»). Når denne nedgangen ikke inntreffer før i *slutten* av boreal tid i diagrammet fra Oddernes skole, er det derfor rimelig å anta at rent lokale forhold her ligger til grunn. De høye boreale NAP-verdiene må henge sammen med den rent lokale urtevegetasjonen på selve myrkomplekset. Dette bekreftes da også av at urtepollenet så å si forsvinner i og med at myrkomplekset blir oversvømmet av havet i slutten av boreal tid (se s. 324). Riktignok fullbyrdes denne oversvømmelsen nettopp som oren innvandrer og alm og eik rykker frem. Men det kan likevel ikke være tvil om at det først og fremst er drukningen av lokalvegetasjonen som er skyld i at urtepollenet plutselig faller nesten 50 % (fra 52 til 3,5 %).

Sone VI—VII — atlantisk tid:

I likhet med forholdene i Fluetjern og særlig «Cladiumtjern» viser ekblandskogen også her en typisk trinnvis stigning. Fra lave verdier på rundt omkring 1 % i sone V skjer det, som allerede nevnt, et plutselig sprang på overgangen til sone VI, til verdier på en 6—7 %. Kurven holder seg på dette nivå fra 210 til 140 cm under overflaten. Her skjer det et nytt sprang, til verdier på 15 % og mer. QM-diagrammet viser at det er innvandringen av lind og fremrykkingen av eik som er årsak til det sistnevnte spranget. Da det nettopp er etableringen og stigningen i lindekurven som definisjonsmessig fastlegger sonegransen VI—VII, har jeg trukket denne grensen ved 135 cm dyp. Den trinnvise stigningen i ekblandskogen forekommer også i en rekke av diagrammene fra Oslo-trakten, men selve innvandringsrekkefølgen for de enkelte ekblandskonstituentene er her noe forskjellig.

Fra sonegrensen VI—VII opp til 20 cm under overflaten er ekblandskogkurven riktignok temmelig ujevn, men den pendler stort sett omkring en middelverdi på en 15—16 %. Det er først og fremst eika som er årsak til at ekblandskogskurven er så ujevn. Kurven for alm og lind har nemlig et jevnere forløp og avviker bare ubetydelig fra 3 prosent-linjen. Men i de øverste 2—3 spektrene skjer det atter et voldsomt sprang i ekblandskogskurven. Dette spranget skyldes utelukkende en rent eksplosiv økning av lindepollenet, fra under 4 % 20 cm under overflaten til over 12 % i overflatespektret. For den moderate økningen av eikepollenet (fra et gjennomsnitt på ca. 9 % til 11—12 %) oppveies til en viss grad av fallet i almekurven. Dette voldsomme spranget i lindekurven mangler et hvert sidestykke i noen av de andre diagrammene og må trolig tilskrives rent lokale forhold. Det er i hvert fall vanskelig å gi noen generell forklaring på at linden plutselig skulle rykke frem over større områder, mens almen, som jo er mer hårdfør, skulle gå tilbake. Det er mulig at lindestigningen kan være en effekt av at området omkring Oddernes skole nå igjen er i ferd med å isoleres fra havet, sml. den tydelige uttynningen av de marine indikatorene *Hystrix* og *Discorbina* samt økningen av *Filipendula*-pollen og *Sphagnum*-sporer mot toppen av diagrammet. På den annen side har jeg ikke kunnet påvise et eneste sikkert spor (pollen av kulturplanter og ugress) som kunne tyde på at det påtagelige fallet i almekurven skyldes menneskelig aktivitet (jordbruk og husdyrhold). Da sonegrensen VII—VIII nettopp er definert ved *Ulmus*-kurvens fall, har jeg rent tentativt trukket denne sonegrensen i 15 cm dyp. Det faktum at transgresjonsfasen tydeligvis tar slutt like over denne sonegrensen, altså i den første delen av subboreal tid, synes å passe godt med det vi vet om varigheten av denne transgresjonen fra Bømlo, Jæren og Haugesund-trakten (se Fægri 1944, 1940, Hafsten 1953).

Den relativt rikelige forekomsten av utpreget varmekjære eller frostømfintlige planter som bergflette (*Hedera*), misteltein (*Viscum*) og kongsbregne (*Osmunda*) like fra øvre halvpart av sone VI og oppover, viser med all tydelighet at det virkelig er den postglasiale høyvarmetiden som her manifesterer seg pollenanalytisk. Forekomsten av bergflette vitner om milde vintre og oseaniske klimaforhold, mens misteltеinen er en indikator på høy sommertemperatur og et noe mer kontinentalt klima (se Hafsten 1957). Det at misteltеinen viser en tendens til å bli hyppigere mot toppen av diagrammet, synes å tyde på at klimaet nå var i ferd med å bli noe mer kontinentalt, — og dermed at sonegrensen VII—VIII er riktig plasert.

Ephedra distachya-type. Av spesiell botanisk og vegetasjonshistorisk betydning er de 4 nye pollenfunnene av *Ephedra distachya*-type som er kommet for dagen ved denne undersøkelsen. De er skrevet inn i AP-diagrammet. Jeg har allerede i mitt 1956-arbeide beskrevet en rekke pollenfunn av denne planten fra Oslo-trakten og særlig Sørlandet (Søgne og Lista). Siden den tid er imidlertid en rekke nye funn blitt gjort, og det kan nå neppe herske tvil om at denne, for vår flora fremmede steppe- og ørkenbusken må ha hatt en alminnelig utbredelse i Sør-Norge i tiden før et sammenhengende skogdekke hadde etablert seg, først og fremst i preboreal og tidlig boreal tid. Det som derfor gjør *Ephedra*-funnene fra Oddernes så interessante, er at de alle sammen, men særlig de to øverste, stammer fra en tid da skogdekket var sammenhengende og tett. *Ephedra*-kornet fra 110 cm dyp er til og med yngre enn innvandringen av lind og ask. Vi har følgelig her en parallell til mitt *Ephedra*-funn fra Stovivannet i Bærum, som også daterer seg til tiden etter linde-ekspansjonen (Hafsten 1956 pl. 10). Det er karakteristisk at nettopp dette vannet ligger tett opp til den gamle forkastningslinjen som gjør at Ramsåsens lavadekker faller stupbratt av mot kambrosilurstrøket like nord og vest for det indre Oslofjordsbassenget. I disse bratte skrentene har skogen aldri kunnet vokse, så her har *Ephedra* hatt vekstbetingelser selv lenge etter at skogen hadde skygget ut den slags heliofile (lyselskende) planter fra resten av området. Da terrenget like nord for det flate terrasselandskapet fra Kongsgårdsletta nordvestover over Gimlemoen til Otra også er temmelig kupert, sml. f. eks. Preståsen like nord for Oddernes skole (fig. 1), ligger det nær å forklare de merkelige *Ephedra*-funnene fra atlantisk tid på liknende måte. Åsene på Sørlandet er dertil, selv i våre dager, så tørre og skrinne at skogdekket her sjelden blir særlig tett. Det er derfor ingen vanskelighet å forestille seg at en steppeplante som *Ephedra* hadde muligheter for å vokse her, selv lenge etter at skogen hadde gjort sitt inntog i disse trakter.

Datering av furustammene

Det skal innrømmes at sålenge de pågående pollenanalytiske undersøkelser på Sørlandet ennå ikke er avsluttet, kan plaseringen av sonegrensen VI—VII og VII—VIII foreløbig være gjenstand for diskusjon. Men det er sonegrensen V—VI som er av betydning for dateringen av furustammene. Og denne grensen er så veldefinert og skarp at det ikke kan herske noen tvil om at den er å plasere omkring 215 sentimeter-nivået. Under dette dypet, helt ned i sandlaget som stammene hvilte på, har vi et rent borealt diagram. Men det er tydelig at sonegrensen IV—V befinner seg like under torvlaget. Det er som kjent Corylus-kurvens begynnelse (C°) som definerer denne sonegrensen. Furumyrtorven faller altså i sin helhet innenfor pollensone V eller boreal tid. De subfossile furustammene, som ifølge Naklings innberetning lokaliserer seg til den nederste delen av torvlaget, kan derfor *med stor sikkerhet dateres til boreal tid, presumptivt til den første delen av denne periode.* Ifølge svensk varvkronologi (sml. FROMM 1938) går den boreale perioden fra ca. 7000 til 5500 år f. Kr. Disse data er nylig blitt bekreftet ved en rekke moderne C^{14}-analyser, blant annet fra Vestfold (foretatt av Laboratoriet for radiologisk datering ved Norges tekniske høyskole, upubl.). Konklusjonen blir derfor at *de subfossile furustammene fra Oddernes er bortimot 9000 år gamle.* Det er å håpe at Laboratoriet for radiologisk datering om ikke altfor lenge vil finne tid til å foreta en radiologisk bekreftelse av denne, rent pollenanalytiske, dateringen av trestammene fra Oddernes.

Den rikelige forekomsten av hassel og furu tyder på at borealtiden hadde et relativt varmt og tørt klima. På grunnlag av sine tregrense-undersøkelser sluttet HELLAND (1912) at furuen må ha en gjennomsnittstemperatur for juni-september på minst 10,5° C for å oppnå en god frømodning. Hasselen synes å være ennå mer varmekrevende, og den raske fremrykkingen av disse treslagene i boreal tid tyder på at sommertemperaturen neppe har ligget under 12,5°. Da gjennomsnittlig sommertemperatur for Kristiansand, Oksøy og Mandal i dag ligger på 14,1°, synes ikke sommertemperaturen under boreal tid å ha vært vesentlig lavere enn i dag. Dette styrkes også av det ene *Cladium*-pollenkornet som ble funnet i 270 cm dyp. Ifølge HOLMBOES (1924) undersøkelser ser det nemlig ut til at halvgresset storâk trenger en gjennomsnittstemperatur for varmeste måned på 14—16° forat normal blomstring skal finne sted.

Landhevningsforhold

Det primære mål for denne undersøkelsen var å datere de subfossile trestammene. Men undersøkelsen har også avslørt forhold som er av generell interesse når det gjelder nivåforandringene under postglasial tid.

Det fremgår av kartet (fig. 1) at Oddernes skole befinner seg nær 10 meter-koten. Ifølge Ingeniør Becks Oppmåling ligger terrengoverflaten der prøveserien ble tatt 9,5 m o. h. Men de oppmålte profilene viser at terrenget her er noe skrånende. Bare 25 m vestenfor prøvestedet ligger overflaten 11,5 m o. h. Terrenget i Kristiansand og den søndre delen av Oddernes er i det hele meget flatt og lavt og består vesentlige av løsavleiringer. Fra Kongsgårdbukten stiger terrenget (Kongsgårdsletta) svakt vestover mot Oddernes skole som ligger en 8—900 m fra sjøen. Langs Prestbekken er stigningen ennå mindre. 10 meter-koten går her helt inntil foten av Preståsen. Den flate delen av Gimlemoen, som begynner noen hundre meter nordvest for Oddernes skole, har en høyde på ca. 20 m, men det er her målt terrasseflater helt opp i vel 25 m høyde.

På grunnlag av funn av hvalknokler og arktiske skjellformer ved Kolsdalstjernet like vest for Kristiansand by, i 14 m høyde, regner DANIELSEN (1957) med en havstand på over 20 m i senglasial tid. Nå foreligger det ingen sikre data for marin grense så langt ute, men i Raet ved Birkenes og Vennesla, vel en mils vei fra kysten angir Danielsen en marin grense på henholdsvis 53,5 og 50 m. Danielsen regner derfor med at marin grense ved Kristiansand neppe ligger over 40 m. Det er ennå for tidlig å ta standpunkt til disse data. Vi kan bare konstatere at prøveserien fra Oddernes skole klart og tydelig viser at dette stedet var isolert fra havet allerede ved begynnelsen av boreal tid. For hverken torvlaget eller de 20 øverste sentimeterne av det underliggende sandlaget, som det foreligger prøver fra, inneholdt marine indikatorer. Da prøveserien er 3,5 m dyp, betyr dette at den delen av området som ligger over det nåværende 6 meter-nivå var tørt land allerede for ca. 9000 år siden.

Transgresjonsfasen 215—0 cm under overflaten.

Såvel lagfølgen som alternansen mellom ferske og marine indikatorer omkring 215 cm under overflaten vitner som nevnt om at en transgresjon av havet fant sted ved Oddernes skole i begynnelsen av atlantisk tid. Myrvegetasjonen drukner (se TOTAL-diagrammet), den terrestriske torvdannelsen opphører og det blir i stedet avsatt marin leirgytje. Lokale ferskvannsindikatorer som *Potamogeton*, *Menyanthes* og *Pediastrum* forsvinner, mens marine indikatorer som *Ruppia*, *Hystrix* og *Discorbina* og typiske havstrandplanter som *Elymus arenarius* (strandrug), *Plantago maritima* (strandkjempe) og arter som hører til familien *Chenopodiaceae* (meldefamilien) — se NAP-diagrammet — begynner å opptre. Selvom enkelte av de marine indikatorene riktignok blir sjeldnere mot toppen av diagrammet, er det ikke tvil om at gytjelaget er marint helt til topps. Forutsatt at soneinndelingen er riktig, betyr dette at stedet var oversvømmet av havet like fra begynnelsen av atlantisk til et stykke ut i subboreal tid. Da transgresjonsfasen begynner ca. 215 cm under overflaten, betyr dette at i det minste alt land som i dag ligger under ca. 7,35 m o. h. var oversvømmet under dette tidsrum. Tykkelsen på det marine leirgytjelaget viser at transgresjonen minst må ha vært 2 m.

Da denne transgresjonsfasen nettopp korresponderer med atlantisk tid, kan det neppe være tvil om at det er den såkalte Tapes-transgresjonen som her fremtrer så klart og tydelig. Denne transgresjonen er påvist i en rekke strøk som ligger i utkanten av siste istids nedisningsområde. På Bømlo og Jæren har Fægri påvist en midlertidig regresjon midt under denne transgresjonsfasen, slik at Tapes-transgresjonen her egentlig er delt i en eldre (tilsvarende den egentlige Littorina-transgresjonen) og en yngre fase. På den danske Kattegatkysten har IVERSEN (1937, 1943) påvist hele tre slike regresjoner, slik at vi her har en fire-delt Tapes- eller Littorina-transgresjon. I diagrammet fra Oddernes skole forekommer det bare én sammenhengende transgresjonsfase. Men det forhindrer ikke at det også i Kristiansand-trakten kan ha forekommet liknende oscillasjoner som på Bømlo, Jæren eller den danske Kattegat-kysten. De videre undersøkelser vil forhåpentligvis bringe klarhet i dette forhold.

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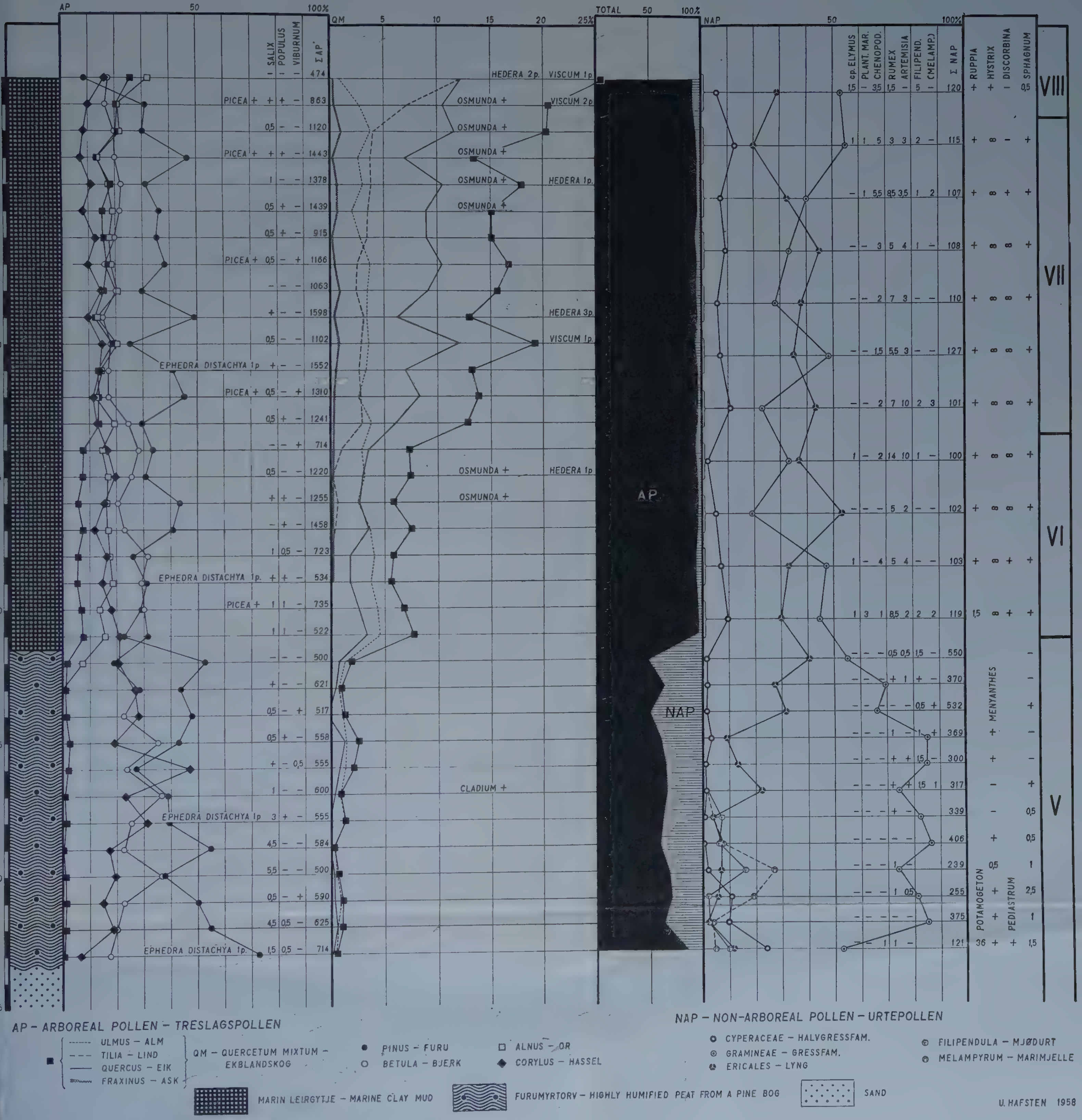
Oddernes skole, Oddernes, Vest-Agder. 9,5 m s.m.



GEOLOGICAL AND PETROLOGICAL INVESTIGATIONS IN NORTHERN TRØNDELAG, WESTERN NORWAY

By

TOR BIRKELAND

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Abstract. Recent geological investigations in northern Trøndelag, western Norway, prove the existence of two distinct tectonic units: (1) a basal rock system (termed the basement complex) which is part of a pre-Cambrian mountain chain, and (2) an overlying system of folded and metamorphosed early Paleozoic supracrustal rocks with intrusives.

The first section of the present paper deals with the rocks of the basement complex. A supracrustal rock system, comprising regionally metamorphosed geosynclinal sediments and basic volcanics, is described. These rocks have been intruded by small bodies of basic and ultrabasic composition. In the later orogenic phase, the supracrustal rock system, after having been intensely folded and metamorphosed, was invaded by huge quantities of granitic magmas.

The second section of the paper deals with the early Paleozoic rock system. The Paleozoic rocks include more or less metamorphosed Cambro-Ordovician geosynclinal sediments and effusives, which have been intruded by ultrabasic, basic, and acid magmatic masses. During the Caledonian orogeny, the geosyncline was squeezed together into deep folds, which trend broadly NNE-SSW.

In the third section of the paper, the relation of the basement complex to the Caledonian zone of deformation is discussed. The results of both field and laboratory work confirm the old conception of this complex as representing the deformed but otherwise unaltered pre-Cambrian basement upon which the Cambro-Ordovician supracrustal rocks originally accumulated.

Introduction

The present paper is based primarily on field geological investigations carried out by the writer in the summers of 1950—52 and 1955—56. The principal aim of these field studies was to clear up the boundary relations of the basement complex to the overlying, folded and metamorphosed early Paleozoic rocks. The writer would like to stress that on account of the cursory character of the investigations in many parts of the area concerned, especially within the basement region, the results achieved are to some extent preliminary as they may be the object of later revisals. Nevertheless, he is of the opinion that the geology of the area may, in its broad features, be substantially correctly interpreted.

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Some of the laboratory work was performed in the years 1947—49, when the writer held a temporary appointment as assistant at the Geological Institute of the University of Bergen. For that opportunity to continue his studies in geology, the writer wishes to express his sincere thanks. The writer is especially indebted to professor Dr. NIELS-HENR. KOLDERUP, the director of the Institute.

ELLEN IRGENS has been responsible for the photomicrographs, and for the drawing of the map, Plate III, while the thin sections were prepared by MARTIN SØGNEN.

WENDY HOLTEDAHL, M. A. has kindly suggested corrections in the English text.

Previous Investigations

Observations from the area were published by TH. KJERULF in 1871, 1876 and 1879. His paper from 1876, containing a map produced in co-operation with K. HAUAN, gives in particular a fairly good description of the geology of the area investigated.

J. REKSTAD in 1909 published a map with a description of the Bindal and Leka districts. A new map with a description of the outer parts of the Helgeland district followed in 1917.

In the period 1920—40, thorough field studies were carried out by the late S. FOSLIE in the eastern and southeastern outskirts of the map area. Unfortunately, none of the results which might have been of consequence to the interpretation of the geology of these parts of the area were ever published.

Detailed field geological investigations have recently been made by H. CARSTENS (1955) in the Snåsa syncline and the adjoining parts of the basement region.

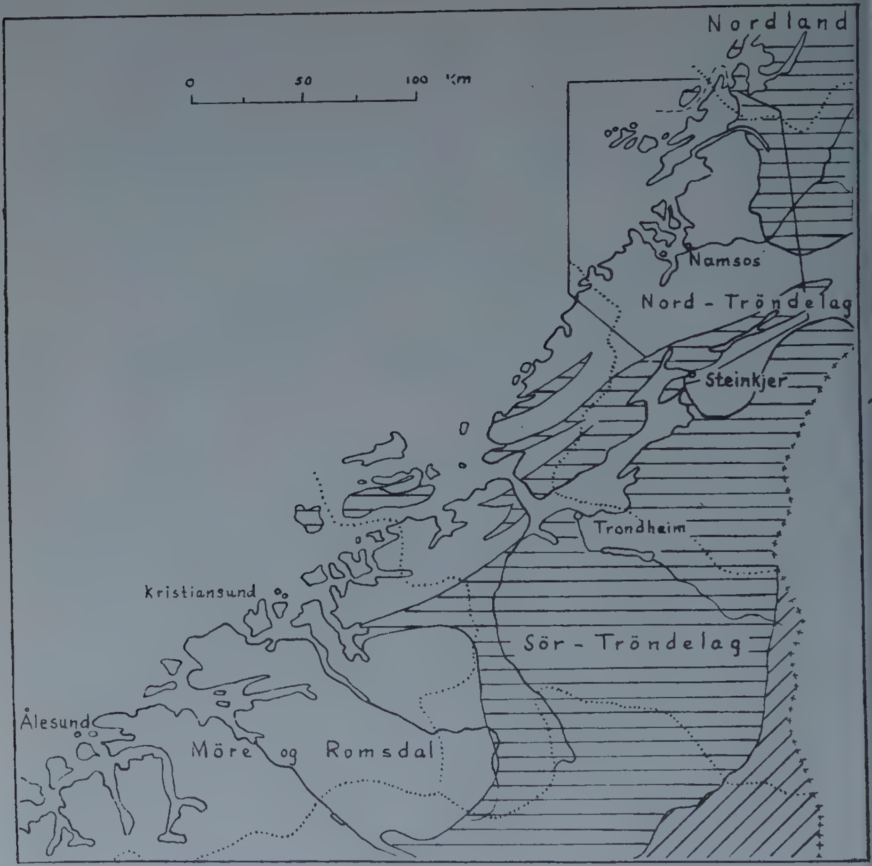

Fig. 1. General geological map of the northern part of southern Norway, showing location of the area investigated. White = basement complex. Diagonal ruling = Eo-Cambrian sparagmite system. Horizontal ruling = system of folded and metamorphosed Cambro-Silurian supracrustal rocks with intrusives.

General Field Relations

The location of the area investigated is indicated on the map Fig. 1. The area covers practically the whole of the territory represented by the rectangular sheets of Vikna, Leka, Fosnes, Høylandet, Namsos and Overhalla, and, in addition, a great portion of the rectangular sheets of Snåsa and Steinkjer. Scattered observations have also been made in the adjoining districts, comprising the rectangular sheets of Trones, Sanddøla, Jævsjø, Ramsøy and Bjørnør.

Geologically, most of the area belongs to the so-called "Vestrand", a geographical-geological concept having been introduced by KJERULF (1871, 1876, 1879) for the coastal region extending from the vicinity of Ålesund, in the Sunnmøre district, to the boundary between the counties of Nordland and northern Trøndelag (Fig 1).

According to the idea advanced in this paper, it is assumed that the great bulk of the area concerned is also part of the pre-Cambrian basement of the Caledonian orogenic zone in northern Trøndelag (Fig. 1 and Pl. III). Here, the basement complex forms an axial culmination in the Caledonides, represented by a "barrier" of land which has its direct continuation eastwards into the pre-Cambrian of Sweden. Just north of this relatively narrow "barrier" is situated the Bindal-Grong depression, which constitutes the southern extremity of the Nordland synclinorium. This geological formation, with its imposing masses of Caledonian supracrustal and intrusive rocks, can be followed in a northeasterly direction through most of northern Norway. At the extreme west, and separated from the Bindal syncline by a northward projecting tongue of the basement complex, is the Leka district, a small area made up of low-grade metamorphic, basic and ultrabasic intrusive rocks and steeply dipping layers of conglomerate, feldspathic sandstone and phyllite. To the south of the above-mentioned "barrier" of land lies the Trondheim synclinorium, a system of more or less folded and metamorphosed Cambro-Silurian rocks which, extending northwards in a fingerlike fashion, finally dies out in the WSW-ENE-oriented Snåsa syncline.

THE BASEMENT COMPLEX

PETROGRAPHY

Sedimentary Rocks

Quartzite

A few occurrences only will be mentioned here: (1) The border zone on the north side of the lenticular, northeast-trending Laugnes granite massif, in the parish of Nærøy. The quartzite appears in a system of subparallel, narrow zones together with thin layers of mica schist and quartzofeldspathic gneiss. (2) The northeastern slope of the mountain of Kjøringsvassfjell, west of Kongsmoen (at the head of Indre Folden fjord). The quartzite is locally found in alternation with quartz schist and quartzofeldspathic gneiss. (3) The narrow part of the basement region cropping out on the south side of the Snåsa syncline, southeast of the eastern end of Lake Snåsa vatn. The quartzite occurs in one broad zone (maximum width about 1 km) and a few thinner ones. Other supracrustal rocks present, partly found in alternation with the quartzite, are mica schist, gneiss and metabasalt.

The quartzite is light grey to darker grey in color. The following minerals have been found: quartz, potash feldspar, acid plagioclase, muscovite, biotite, garnet, further tourmaline, zircon, apatite, pyrite and magnetite.

The quartz, as the chief mineral, forms about two thirds of the rock.

The potash feldspar is the mineral next in importance. It is microcline, sometimes also microcline microperthite.

The plagioclase, which is oligoclase (An_{15-20}), is present only infrequently. Myrmecite is rare.

The muscovite is a normal constituent of the quartzite, but is commonly present in small quantities.

The biotite, which as a rule occurs in still smaller amounts than the muscovite, is brown with a tinge of red.

The garnet (almandite) occurs, when occasionally present, in very small grains.

Common accessory minerals are zircon, apatite and magnetite.

Quartz Schist

Quartz schist may locally be found in alternation with quartzite, mica schist, micaceous gneiss, or quartzofeldspathic gneiss. The chief minerals are quartz and muscovite. Other constituents are biotite, acid plagioclase, potash feldspar and garnet, further zircon and apatite in accessory amounts.

The quartz shows undulatory extinction.

The plagioclase is oligoclase (An_{20}). It is twinned, usually according to the albite law.

The potash feldspar is microcline, rarely microcline microperthite.

The mineral occurs in highly varying quantities. In some thin sections it forms small, distinct grains alongside those of plagioclase, while in others it is found only as insets in the plagioclase; it may also be entirely absent.

As regards the micas, the content of muscovite generally outweighs that of biotite. The biotite is strongly pleochroic, and brown to reddish brown, with darker colors around inclusions of zircon.

The garnet (almandite) has been found in crystals of up to 1 cm across.

Mica Schist

The following localities may be mentioned: (1) The belt of metamorphosed supracrustal rocks in the northern part of the Laugnes peninsula. The mica schist is found just north of the granite body in a few thin, subparallel zones in alternation with quartzite and various gneisses. The largest of these zones has a maximum thickness of about 10 m. (2) The central mountainous district about halfway between Namsos and the eastern part of Lake Snåsa vatn. A relatively wide zone of garnet-bearing mica schist appears on the eastern slope of the mountain Grønhaugen, but as the mica schist dips gently northwestwards, the thickness of this zone can probably not be great. (3) The belt of gneiss and metabasalt east of the large granite-granodiorite massif of the mountain Gjeitfjellet, north of the eastern end of Lake Snåsa vatn. Two comparatively wide zones of interbedded gneiss and a little mica schist occur. (4) The anticlinal area south of the Snåsa syncline. In the zones of quartzite, gneiss and metabasalt, may occasionally be found thin layers of mica schist.

The mica schist is grey in coloring. Its chief components are quartz, muscovite and biotite. Less important are plagioclase and garnet, while potash feldspar is apparently present only very infrequently. Accessory minerals are tourmaline (rare), zircon, apatite and magnetite.

The quartz often has strong undulatory extinction.

The plagioclase is oligoclase (An_{20} to An_{25}). Twinning on the albite and pericline laws is common.

The potash feldspar is microcline. When rarely present, it forms irregular grains between the other constituents, or it may be found as optically oriented insets in the plagioclase.

The muscovite usually occurs in large amounts.

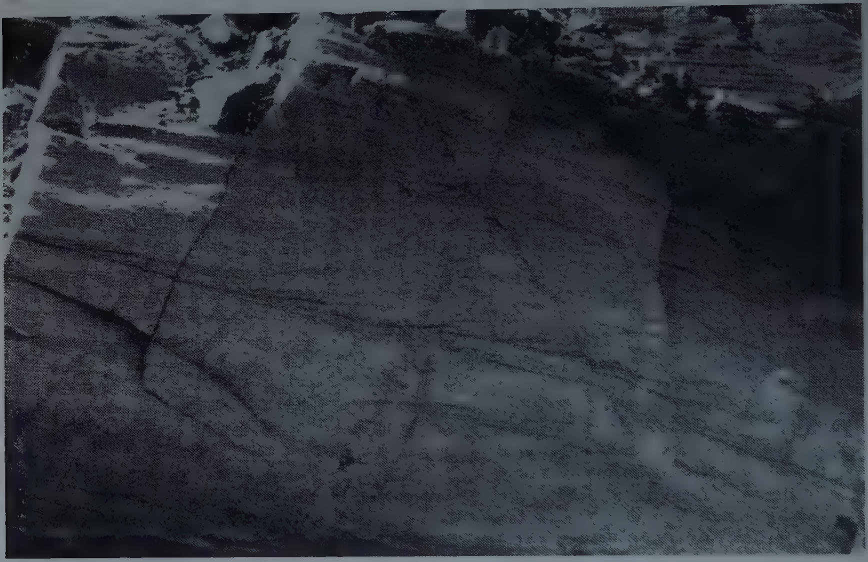

Fig. 2. Cross-bedding in quartzofeldspathic gneiss, type No. 1. From a quarry about halfway between the farms Molisveet and Rannem, 3 km south of Steinkjer.

The biotite is always present, but the content of this mineral varies considerably. The pleochroism is strong with X pale yellow, Y = Z reddish brown. Inclusions of zircon are surrounded by dark pleochroic halos.

The garnet (almandite) may become an important constituent of the rock in some zones (with crystals up to 1 cm in diameter), while it is entirely absent in others.

Common accessory minerals are zircon and apatite.

Gneiss

Gneiss has a wide distribution within the basement region. On an estimate, 90—95 % of the territory occupied by the supracrustal rock system is underlain by gneiss. Petrographically, the rocks may be divided into three groups: quartzofeldspathic gneiss, micaceous gneiss and lime silicate gneiss.

Quartzofeldspathic Gneiss

Megascopically, the members of this group are light-to darker-grey, medium- to fine-grained (not seldom rather compact) gneissic rocks. Bedding, usually coinciding with the secondary foliation, is visible in most cases. Cross-bedding is another primary feature commonly seen in the gneiss which occurs in the district south and east of Steinkjer (Fig. 2).

This gneiss is characterized by the predominance of quartz and feldspar (acid plagioclase and potash feldspar), over the micas (biotite and muscovite) and other rock-forming minerals which may be present. The last-mentioned constituents may be garnet, cummingtonite, an epidote mineral and calcite.

The gneiss can be subdivided into three types:

1. Microcline-plagioclase-biotite-muscovite (-almandite) gneiss.

This type is a grey to light-grey, medium- to fine-grained rock. Occasionally, a vein structure may appear (Fig. 3). The scattered veins, consisting chiefly of quartz and feldspar, are more coarse-grained than the remaining part of the rock, and may locally attain a pegmatitic grain size.

The following minerals have been found: quartz, potash feldspar, acid plagioclase, biotite, muscovite, garnet, further zircon, apatite and magnetite.

The quartz, which is the most important constituent next to the feldspars, has always undulatory extinction.

The potash feldspar is microcline and microcline microperthite. The mineral forms irregular grains among the other constituents.

The plagioclase is intermediate oligoclase (An_{20}). Multiple twinning on the albite and pericline laws is common. Myrmecite is rare.

Of the micas, biotite and muscovite both occur in relatively small amounts. The biotite has the pleochroism: X pale yellow, Y = Z brown to reddish brown. Inclusions of zircon are surrounded by intense pleochroic halos.

The garnet (almandite), when present, forms small grains measuring up to some few mm in diameter.

Accessory minerals are zircon, apatite and magnetite.

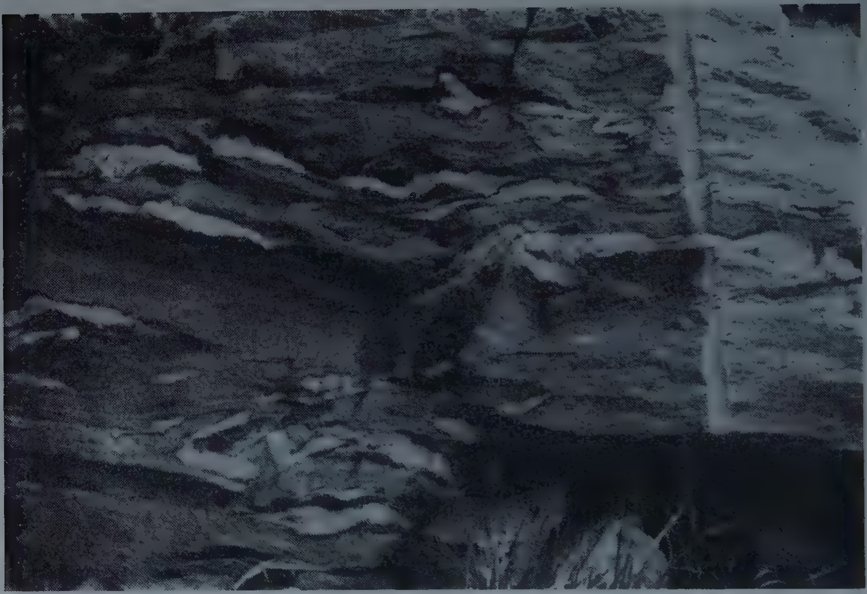

Fig. 3. Vein structure in quartzofeldspathic gneiss, type No. 1. Near the shore, 1 km NE of Valøy railway station, on the south side of Lake Snåsa vatn.

2. Biotite-almandite-cummingtonite gneiss.

The gneiss is a grey, rather compact, medium-grained rock. Structurally, it may be characterized by a more or less distinct banding, caused by the concentration of the light and dark minerals into separate bands.

These minerals have been found: quartz, acid plagioclase, biotite, garnet, cummingtonite, and, in accessory amounts, zircon, apatite, pyrite and magnetite.

The quartz and plagioclase are the chief constituents. The plagioclase, which is intermediate oligoclase (An_{20}), is commonly twinned on the albite and pericline laws.

The biotite, which is the only mica present, has the pleochroism: X pale yellow, Y = Z dark brown to opaque. In the biotite are seen inclusions of zircon with the usual pleochroic halos.

Of the other dark minerals, cummingtonite has not always been found, while a minor content of garnet (almandite) is characteristic.

The cummingtonite forms small prisms, which are almost colorless in thin section. The garnet usually occurs as poorly developed crystals measuring up to 5 mm in diameter. The grains often contain inclusions of quartz, plagioclase and biotite.

3. Biotite-muscovite-clinozoisite-calcite gneiss.

So far, this gneiss type has not been localized outside the wide zone of metasediments appearing in the district between the Gilten and Ytre Bangsjø lakes, just north of the Snåsa syncline. Megascopically, it is a grey to light-grey, medium- to fine-grained rock. Relatively large, dark biotite porphyroblasts often give the gneiss in planes parallel to the schistosity a characteristic, spotted appearance.

The following minerals have been observed: quartz, acid plagioclase, potash feldspar, biotite, muscovite, clinozoisite, calcite, further, in accessory amounts, zircon, apatite, pyrite and magnetite.

The quartz is always present in abundance.

The plagioclase is intermediate-basic oligoclase (An_{20}—An_{25}). It occurs in small, approximately isometric grains, which exhibit twinning on the pericline and albite laws.

The potash feldspar is microcline, less frequently microcline microperthite. When present, it forms small, irregular grains, but may also be found as minute patches in the plagioclase.

The biotite, forming porphyroblasts up to 3 mm in length, has the pleochroism: X pale yellow, Y = Z brown to dark brown, which is intensified in the halos around inclusions of zircon and clinozoisite.

The muscovite is usually found in small or insignificant amounts.

The clinozoisite, forming slender prisms of up to 1 mm in length, may contain cores of orthite-epidote.

The calcite commonly occurs as small, irregular grains measuring up to 1 mm across, but may also be found, locally, as thin stripes and lenses in the gneiss.

In addition to the above-mentioned constituents, traces of a green, pleochroic mineral (probably a member of the amphibole group) have been observed in one thin section.

Micaceous Gneiss

Under this head are grouped gneissic rocks which are characterized by a rather high content of mica. In many cases this mineral is biotite, while in others muscovite (associated with biotite) may become an important constituent of the gneiss.

Micaceous gneiss has a wide distribution within the basement region. In the northwesternmost part of the map area, a broad zone of this rock can be followed from the Nærøy district, in the south, to Sør fjord, about 70 km farther northeast. In the district east of Folden fjord, another zone of this gneiss type is found in the interspace between the two granite massifs represented by the mountains of Skjolden and Kjøringsvassfjell. Micaceous gneiss, often with intervening layers of quartz schist and quartzite, infrequently with beds of mica schist, occurs also in the central and southern parts of the basement region, e. g. in the inner fjord district just north of Namsos, where there is a wide, E-W to SE-NW oriented zone, with sharply defined boundaries to the surrounding massifs of granite and granodiorite. A zone of much lesser dimensions occurs a little southeast of Namdalseid, while, farther east, a somewhat larger belt of micaceous gneiss appears in the mountainous district between the Skjærsjøen and Gilten lakes. The latter zone is connected with a similar belt situated west and northwest of the Bangsjø lakes. Still farther east, in the two areas of gneiss and metabasalt which lie respectively north and south of the eastern end of Lake Snåsa vatn, are found several narrower zones of the rock in question.

As regards the origin and mode of development of the members of this gneiss group, they probably represent strongly metamorphosed arenaceous sediments of a complex character, into which have entered both pelitic and psammitic components.

Petrographically, the micaceous gneiss may be subdivided into various types, which conform to the following mineral associations:

1. Quartz-plagioclase-biotite-muscovite-almandite (-clinozoisite).
2. Quartz-plagioclase-biotite-muscovite-cyanite-almandite.
3. Quartz-plagioclase-biotite-almandite-sillimanite (-cyanite).
4. Quartz-plagioclase-microcline-biotite-almandite-sillimanite.
5. Quartz-plagioclase-microcline-biotite-cordierite-sillimanite.
6. Quartz-plagioclase-biotite-cummingtonite-almandite (-hornblende).
7. Quartz-plagioclase-biotite-anthophyllite-almandite.

Type No. 1 is particularly common in the border districts north and south of the Snåsa syncline. The rocks conforming to the parageneses Nos. 3 and 4 have not been found outside the northwesternmost gneiss area, while, on the other hand, types Nos. 2 and 6 seem to be more widely distributed throughout the basement region. The appearance of rocks corresponding to the mineral assemblage No. 5 is wholly locally conditioned, and the same is perhaps the case with rocks conforming to the paragenesis No. 7.

1. Biotite-muscovite-almandite (-clinozoisite) gneiss.

The petrography of this rock is not well known. Megascopically, it is a grey, medium-grained rock, in many cases exhibiting a distinct bedding which coincides with the secondary foliation. This rock is closely related to type No. 1 of the quartzofeldspathic gneiss dealt with above.

2. Biotite-muscovite-cyanite-almandite gneiss.

This gneiss type is known from widely separated parts of the basement region. As, however, no thin section of the rock has been studied, it is at present impossible to give a full account of its petrography. Megascopically, it is a darker-grey, medium-grained, schistose rock. A reddish-brown garnet (almandite), usually occurring in small grains, is frequently observed. The cyanite forms relatively broad tabular crystals measuring up to 1—2 cm in length. In color the mineral is various shades of bluish grey. As for the micas, biotite is always found, while muscovite may apparently sometimes be absent.

3. Biotite-almandite-sillimanite (-cyanite) gneiss.

This type is a grey to darker-grey, medium-grained, schistose rock, in which small lenses and veins of quartz are often visible. Bedding may be more or less obliterated by strong recrystallization.

The following minerals have been found: quartz, plagioclase, biotite, muscovite, hornblende, garnet, sillimanite, cyanite, further zircon, apatite, pyrite and magnetite.

The quartz, which is one of the main components of the gneiss, always has undulatory extinction.

The plagioclase, which occurs in xenoblastic grains, is twinned on the albite and pericline laws. The twinning may be beautifully developed. The composition of the plagioclase was determined in 5 samples collected from different places within the northwesternmost gneiss zone, with the following results: (1) An_{13}, gneiss extremely rich in biotite, with sillimanite and cyanite. From the Purkholmen islet, near Abelvær. (2) An_{15}, gneiss rich in biotite. From the Brennholmen islet, near Abelvær. (3) An_{27}, gneiss rich in biotite and garnet. From the Brennholmen islet. (4) An_{28}, gneiss with sillimanite. From the summit of the mountain of Tverakslen, northwest of Foldereid church. (5) An_{38}, gneiss. From the southern slope of the mountain of Tverakslen. The composition of the plagioclase thus shows a high degree of variability. This change in the An-content cannot reasonably be attributed to great local differences in the physical conditions during metamorphism: the real cause is more likely to have been a variation in the bulk composition of the original sediment.

The biotite has the pleochroism: X pale yellow, Y = Z reddish brown to dark brown. In the biotite inclusions of zircon with intense pleochroic halos are commonly seen.

Muscovite. Traces of this mineral, sometimes in parallel growth with biotite, are present in a few thin sections only.

The hornblende is rarely met with. It is of the common green type.

The garnet (almandite) occurs in grains measuring between 1 and 5 mm in diameter. The individual grains may or may not have their own crystal boundaries. In the garnet inclusions of quarts, plagioclase and apatite are often found.

The sillimanite usually occurs in small sheaf-like bundles of fine needles.

The cyanite is mostly absent. In a sample from the Purkholmen islet, where the cyanite was found in broad, tabular crystals up to 2 cm long (partly in intergrowth with sillimanite Pl. I, fig. 1), the following optical properties were determined: $Ng = 1.728$, $Np = 1.715$, $Ng—Np = 0.013$, $2V = ca.\ 80°$ over X.

Common accessory minerals are zircon, apatite and magnetite.

4. Biotite-almandite-sillimanite-microcline gneiss.

The rock is a medium-grained, schistose gneiss. In color it is various shades of grey, with darker layers rich in biotite alternating with lighter ones relatively poor in the same mineral — indicative of a primary bedding.

The following minerals have been found: quartz, plagioclase, potash feldspar, biotite, muscovite, garnet, sillimanite, hornblende, further zircon, apatite and magnetite.

The quartz may show strong undulatory extinction.

The plagioclase usually constitutes a considerable part of the gneiss. The grains mostly have a xenoblastic outline. Intergrowths of plagioclase and potash feldspar are frequently seen. The plagioclase is usually oligoclase (An_{20} to An_{25}), rarely andesine (up to An_{40}). Twinning on the albite and pericline laws (often beautifully developed) is common. Myrmecite and myrmecite-like intergrowths of plagioclase and quartz, occurring in small grains, are present in most thin sections. Zoning of the plagioclase is never observed.

The potash feldspar, which is microcline or microcline microperthite, is found in highly varying amounts. Actually, all transitions exist between a gneiss with plagioclase as the only feldspar, and a gneiss in which the two feldspars occur in almost equal proportions. Starting with the former type, the first change to be recognized in the microscope is the appearance of scattered, tiny spots of potash feldspar both within and outside the plagioclase. In some of the plagioclase grains, these spots of microcline gradually take the form of small, short insets which may be terminated by crystal planes. On growth, two or more of these insets may coalesce to larger, somewhat irregular masses, giving the plagioclase a patchlike structure. At times, another type of composite feldspar has been developed, the microcline being found as labyrinthic masses in the plagioclase. Outside the plagioclase individuals, the microcline occurs as irregular grains of varying size between the other constituents.

The biotite is usually found in rather large amounts. The pleochroism is: X pale yellow, Y = Z reddish brown to almost opaque. In the biotite inclusions of zircon surrounded by intense pleochroic halos are frequently noted.

The muscovite is present only occasionally.

The garnet (almandite) has been observed in most thin sections. The grains are small, the average size being about 1 mm. The garnet, which may or may not have its own crystal shape, usually forms homogeneous individuals, while a poikiloblastic structure (inclusions mainly of quartz and plagioclase) is more seldom developed.

The sillimanite is not commonly found. The appearance of this mineral is largely restricted to the following localities: (1) At different places in the hilly range represented by the mountains of Tverakslen, Storskarfjell and Kobbergrubfjell, west of Foldereid. (2) At a few places in the district represented by the mountains of Haltussen and Krekling Haltussen, further southwest. (3) The eastern slope of the mountain of Moalien, 2 km south-southeast of Gravvik church. The sillimanite may occur both as separate, rather small prismatic crystals, and in the form of relatively large sheaf-like bundles of fine needles. In other cases, sillimanite is found in compact, flattened aggregates together with biotite and a little garnet. Locally, the sillimanite may show incipient alteration to muscovite.

The hornblende, which is of the common green type, is seldom met with.

Accessory minerals are zircon, apatite, and magnetite.

5. Biotite-cordierite-sillimanite-microcline gneiss.

This type is found quite exceptionally. In fact, it has been observed only once — on the western slope of the mountain of Høgråna, east of Rørvik. The gneiss appears in one small lentoid mass, which lies enclosed in a medium-grained, foliated granodiorite. The strike of the rocks is very near NE-SW, the dip being steep towards the southeast.

The color of the rock is comparatively dark, owing to a larger content of a greenish-black biotite. Other minerals directly observed are quartz, feldspar and a greyish mineral which on closer examination appears to be sillimanite. Cordierite is also visible megascopically, although this mineral can most easily be mistaken for quartz.

The microscope reveals the following minerals: quartz, acid plagioclase, potash feldspar, biotite, muscovite, cordierite, sillimanite, and zircon. (Pl. I, fig. 2).

The quartz exhibits undulatory extinction.

The plagioclase, which is acid oligoclase (An_{12}), shows polysynthetic twinning. In the plagioclase may be found small, optically oriented insets of potash feldspar. Occasionally, several such insets may coalesce, thereby forming larger, irregular masses of potash feldspar within the plagioclase grains. Myrmecite is present in small amounts.

The potash feldspar is microcline. It is found both as individual xenoblastic grains and as intergrowths in the plagioclase.

The biotite has the pleochroism: X colorless, $Y \doteq Z$ pale brown. Inclusions of zircon are surrounded by the usual pleochroic halos.

The muscovite is present in minor amounts only.

The cordierite is colorless in thin section. The following optical constants were measured: Ng = 1.547, Np = 1.541, Ng—Np = 0.006. The optic angle is large. Characteristic is the presence of pleochroic halos around inclusions of zircon, the halos assuming a deep-yellow color when parallel to X. In the cordierite are also found inclusions of sillimanite, small needles which are oriented in a common direction.

The sillimanite occurs partly in relatively large, slender prisms (up to 2 cm in length), partly in fine needles, in the latter case often with an arrangement of sheaf-like bundles. The sillimanite is sometimes found in parallel growth with biotite.

6. Biotite-cummingtonite-almandite (-hornblende) gneiss.

Megascopically, it is a dark-grey, medium-grained, schistose rock. The gneiss is often rather heterogeneous, with alternating, differently composed thin layers in which the ratio between the light- and dark-colored constituents may be subject to great variations (most likely a structural feature inherited from the parent sediment, but now to some extent obliterated or blurred by recrystallization).

The following minerals have been found: quartz, acid plagioclase, biotite, cummingtonite, garnet, hornblende, further zircon, apatite, pyrite and magnetite.

The quartz is one of the chief constituents of the gneiss. It shows undulatory extinction.

The plagioclase is intermediate-basic oligoclase. Multiple twinning on the albite and pericline laws is common.

The biotite has the pleochroism: X pale yellow, Y = Z reddish brown, which is intensified around inclusions of zircon.

The cummingtonite is dark green (with a tinge of brown) in hand specimen. In thin section, it is weakly pleochroic with X = Y colorless to very pale yellowish, Z pale brownish grey. The optic angle is large with varying sign, ranging from $(+2V) = 80°$ to $(-2V) = 85°$ approximately. $Z \wedge c = 16°—19°$. Now and then, the cummingtonite crystals may show lamellar twinning.

The garnet (almandite) forms grains measuring up to 1 cm across. The larger individuals may contain numerous small grains of other minerals.

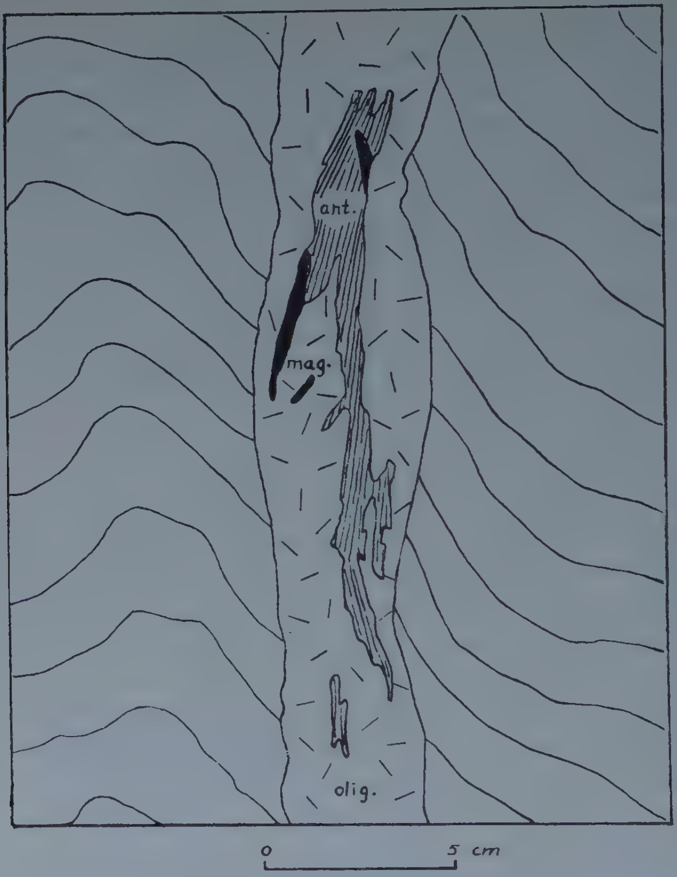

Fig. 4. Coarse-grained vein traversing a hornblende-biotite-garnet-bearing lime silicate gneiss. Olig. = oligoclase; ant. = anthophyllite; mag. = magnetite. From Purkholmen near Abelvær.

The hornblende, which is of the common green type, seems to be of rare occurrence.

Accessory minerals are zircon, apatite, pyrite and magnetite.

7. Biotite-anthophyllite-almandite gneiss.

This type has been found only once — on the islets of Purkholmen and Lille Kalvøy, near Abelvær, where it occurs intimately associated with other gneiss types.

The following minerals have been observed: quartz, acid plagioclase, biotite, anthophyllite, garnet; further, zircon, apatite and magnetite in accessory amounts.

The plagioclase is basic oligoclase (An_{30}). It is well twinned.

The biotite is brown in coloring.

The anthophyllite occurs in comparatively broad prismatic crystals which, attaining a length of up to 4 cm, may be radially arranged. Large crystals of this mineral have also been found in some of the light-colored, coarse-grained veins (consisting mainly of acid plagioclase) which intersect the gneiss complex (Fig. 4). The color of the anthophyllite is of a greyish brown. Under the microscope it is weakly pleochroic, with X nearly colorless, Z very pale brownish grey. The optic angle is large, with $2V = 80°—85°$ over Z. One determination of the refractive indices was made, with the following result: $Ng = 1.675$, $Np = 1.655$, $Ng—Np = 0.020$. In the diagram of WINCHELL (1933, p. 242), these figures correspond to a member of the anthophyllite series, with about 47 per cent of Fe-silicate.

The garnet (almandite) may form crystals measuring up to 1 cm in diameter.

Lime Silicate Gneiss

This gneiss group may be divided into hornblende-biotite-bearing and diopside-bearing types. The bulk of these rocks are found north and northwest of a line drawn from Grong railway station to Namdalseid church.

Hornblende-biotite-bearing gneiss. The members of this gneiss type are darker, medium-grained rocks. Preponderance of hornblende results in amphibolitic types, while an increase in the content of biotite leads to rock types that are transitional to the micaceous gneiss.

The gneiss may be subdivided into two types:

1. Hornblende-biotite-cummingtonite-almandite gneiss.

Hornblende and plagioclase are the principal minerals (Fig. 5). In varying, although usually comparatively small amounts, occur quartz, biotite, cummingtonite and garnet. Diopsidic pyroxene has been observed, but is apparently mostly absent. Sometimes, a well-developed banding with alternate dark and lighter bands is seen in the rock; for example, hornblende and cummingtonite may be associated in such a

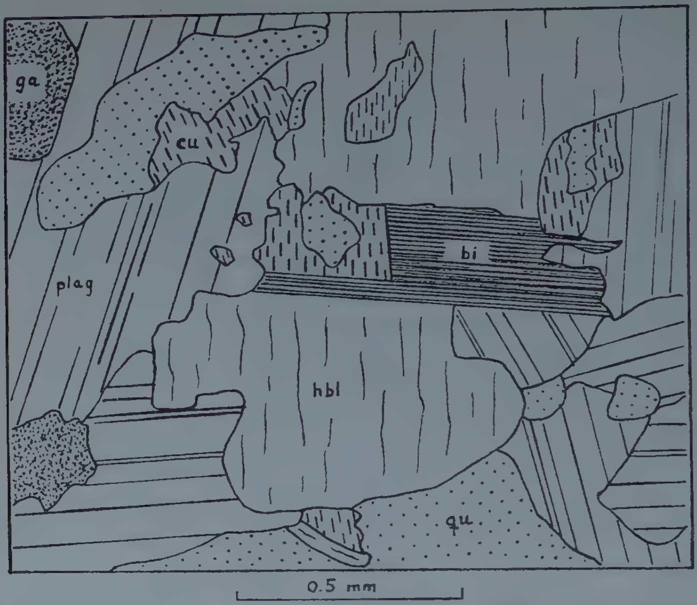

Fig. 5. Cummingtonite-garnet-bearing hornblende-biotite gneiss. From Brennholmen near Abelvær.

way that hornblende is chiefly found in the dark bands while most of the cummingtonite is restricted to the lighter ones.

The hornblende is greenish black in color. Under the microscope it is strongly pleochroic, with X pale yellowish green, Y green to brownish green, Z green to darker green. The optic angle is large, with $(-2V) = 70°—80°$. $Z \wedge c = 17°—20°$. These refractive indices were determined in a sample from Laugval, in the parish of Nærøy: $Ng = 1.670$, $Np = 1.650$, $Ng—Np = 0.020$ approximately.

The plagioclase is intermediate to basic oligoclase. It is always twinned, usually on the albite and pericline laws.

The biotite has the pleochroism: X pale yellow, Y = Z brown to reddish brown.

The cummingtonite is green to greenish grey in specimen. In thin section it is weakly pleochroic, with X = Y colorless, Z very pale yellowish. The mineral, which may show lamellar twinning, is biaxial positive with $(+2V) = 75°—85°$. The following optical properties were determined in a specimen collected from the above-mentioned locality: Ng = 1.664, Np = 1.638, Ng—Np = 0.026, $Z \wedge c = 19°$, $(+2V) = 75°$ approximately. In the diagram of WINCHELL (p. 244), these figures correspond to a cummingtonite with about 60 per cent of Mg-silicate.

The garnet (almandite) forms crystals up to 2 mm in diameter.

The diopsidic pyroxene is pale greenish grey in thin section. The pyroxene is biaxial positive with $(+2V)$ = ca. 60°.

The quartz is present in highly varying amounts.

Accessory minerals are zircon, apatite, magnetite, pyrrhotite and calcite.

2. Hornblende-biotite-microcline (-almandite) gneiss.

Hornblende and plagioclase, as in the preceding type, are the chief constituents, while the content of potash feldspar, biotite, garnet and quartz is subject to considerable variations. Other minerals occasionally found are diopsidic pyroxene, clinozoisite, epidote and calcite.

The hornblende is dark green to almost black in specimen. The pleochroism is strong, with X pale yellowish green, Y green to yellowish green, Z green to deep green (sometimes with a tinge of blue). The mineral is biaxial negative, with $(-2V) = 45°—85°$. $Z \wedge c = 18°—23°$. More complete optical determinations were made in samples from the following localities and with these results:

a) Abelvær (flakelike inclusion in foliated granite). Ng = 1.700, Np = 1.682, Ng—Np = 0.018, $Z \wedge c = 20°$, $(-2V) = 45°$ approximately.

b) Fiskholmen, near Abelvær (flakelike inclusion in foliated granite). Ng = 1.691, Np = 1.670, Ng—Np = 0.021, $Z \wedge c = 18°$, $(-2V)$ = ca. 85°.

c) Kjeksvika, near Abelvær (flakelike inclusion in foliated granite). Ng = 1.686, Np = 1.667, Ng—Np = 0.019, $Z \wedge c = 18°$, $(-2V)$ = ca. 85°.

d) Road-cut near Lilleval agric. coll. Ng = 1.669, Np = 1.648, Ng—Np = 0.021, $Z \wedge c = 18°$, $(-2V)$ = ca. 75°.

The plagioclase is basic oligoclase to intermediate andesine (An_{25-45}). It is always twinned, usually on the albite and pericline laws. Zoning of the plagioclase is very rarely observed.

The potash feldspar is microcline. The mineral occurs partly as tiny patches in the plagioclase.

The biotite is strongly pleochroic, with X pale yellow, Y = Z reddish brown to dark brown. Inclusions of zircon are surrounded by intense pleochroic halos.

The garnet occurs in small poikiloblastic grains, averaging 2 mm in diameter. The mineral is probably a garnet with dominating almandite molecule.

The quartz shows undulatory extinction.

The diopsidic pyroxene is nearly colorless in thin section.

The clinozoisite and epidote generally form minute prisms, which may contain nuclei of orthite-epidote.

The calcite is found as small patch-like grains.

In addition to the above-mentioned minerals, scapolite has been observed a few times.

Accessory constituents are titanite, zircon, apatite, pyrite and magnetite.

Diopside-bearing gneiss. The members of this gneiss type are greenish-grey, medium-grained rocks. The chief minerals are diopsidic pyroxene, plagioclase, potash feldspar and quartz. Less important are biotite, garnet, hornblende and calcite. In addition, the following mineral phases have been found: clinozoisite, epidote, titanite, zircon, apatite, pyrite, pyrrhotite and magnetite.

The diopsidic pyroxene occurs in grains (often distinctly prismatic in crystal habit) measuring up to 1 cm in length. Lamellar twinning on 100 is common. The pyroxene, which is almost colorless in thin section, is biaxial positive with $(+2V) =$ ca. 60°. $Z \wedge c = 42°—43°$. The indices of refraction were determined in two samples (from different localities), and with the same result: $Ng = 1.715$, $Np = 1.688$, $Ng—Np = 0.027$. According to the diagram of WINCHELL (p. 226), these figures correspond to a diopside with about 33 per cent of Fe-silicate. A weakly pleochroic amphibole, secondary after diopside, is of rare occurrence.

The composition of the plagioclase lies within the limits of An_{30} and An_{60} (andesine to intermediate labradorite). Twinning on the albite and pericline laws is common. Myrmecite is found in most thin sections.

The potash feldspar is microcline, less commonly microcline microperthite. The mineral occurs in relatively large, irregular grains, but may also be found as small patches in the plagioclase.

The quartz is present in varying amounts. It exhibits undulatory extinction.

The biotite has the pleochroism: X pale yellow, Y = Z reddish brown.

The garnet may form crystals up to 1.5 cm in diameter, but generally the grain size is much smaller. The color varies from red to brownish red. The index of refraction is $N \geqq 1.77$. The composition of the garnet probably corresponds to that of an almandite relatively rich in the pyrope and grossularite molecules.

The hornblende is of the common green type.

The calcite forms small irregular grains, which are evenly distributed throughout the rock.

The clinozoisite and epidote, when present, occur in insignificant amounts only. The individual grains, small prisms up to 0.5 mm in length, may contain cores of orthite-epidote.

Of the accessory minerals, titanite, zircon, apatite and pyrrhotite are commom, while pyrite and magnetite are less frequently found.

Other Lime Silicate Rocks

Skarn rocks

Rocks of this character, forming small lenticular masses in the lime silicate gneiss, are of rare occurrence. A sample collected from a locality just west of Svanås farm in the Gravvik district, shows dark-green pyroxene, brownish-red garnet and a little calcite.

The pyroxene is pale green in thin section, with no visible pleochroism. Some of the grains, however, or even parts of one and the same grain, may be strongly colored, having the pleochroism: X yellowish green, Z dark green. In this case, one is probably dealing with a pyroxene of the ferrous type hedenbergite (the mineral is biaxial positive with $(+2V) =$ ca. 60°). The ordinary pyroxene of this rock is somewhat poorer in Fe-silicate, its optical properties being as follows: $Ng = 1.743$, $Np = 1.722$, $Ng—Np = 0.021$, $Z \wedge c = 47.5°$, $(+2V) =$ ca. 60°. In the diagram of WINCHELL (p. 226), these figures correspond to a member of the diopside-hedenbergite series with an approximate composition $Di_{20}He_{80}$.

The garnet forms up to 2 mm large isotropic grains, which are yellowish brown in thin section. The index of refraction is $N > 1.78$. The mineral is probably an iron-rich member of the grossularite-andradite series.

The other minerals present are calcite, quartz and magnetite, all of which occur in minor quantities only.

Three small lenses of a rock type differing somewhat in mineral composition from the one described above were found in a hornblende-bearing granodiorite at the southern tip of the island of Abelvær, in the Nærøy district. The said xenoliths are oriented with their longest axes parallel to the foliation of the plutonic rock. Two of these lenses, the largest of which is about 40 by 15 cm in size, consist of abundant red garnet, some green pyroxene and quartz, and traces of calcite, while the third has abundant hornblende (nearly black in specimen) and minor amounts of red garnet and quartz. Other minerals are vesuvianite, zoisite, epidote and titanite.

The garnet is isotropic in thin section. The index of refraction is $N = $ ca. 1.760, suggesting a garnet rich in the grossularite and/or pyrope molecules.

The pyroxene is biaxial positive, and has $Ng = 1.730$, corresponding to a ferrous diopside with an approximate composition $Di_{45}He_{55}$.

The vesuvianite occurs in crystals which may attain a length of up to 5 mm. The mineral, which is uniaxial negative, is also partially found as a narrow rim around grains of garnet.

The zoisite forms aggregates of small, irregular grains. It is β-zoisite with $(+2V) = 20°$ approximately.

The epidote is biaxial negative with a large optic angle.

The quartz occurs both as comparatively large masses and in small roundish grains which show a very weak undulatory extinction.

The calcite forms irregular grains, but may also be found as tiny patches in the garnet and pyroxene.

Rocks with abundant diopside

Occasionally rocks may be found which consist chiefly of a well-crystallized, white or greyish-white diopside. In a sample collected from the above-mentioned locality near Svanås farm in the Gravvik district, the following optical properties were determined: $Ng = 1.696$, Np = 1.667, Ng—Np = 0.029, $Z \wedge c = 38°$, which, according to the diagram of WINCHELL (p. 226), correspond to a diopside with about 5 per cent of Fe-silicate. In another specimen taken 5 km farther south were measured: Ng = 1.698, Np = 1.670, Ng—Np = 0.028, $Z \wedge c = 39.5°$, which according to the same diagram give a composition of about 8 per cent of Fe-silicate. In addition to the diopside may be observed minor quantities of quartz, plagioclase (andesine), potash feldspar (microcline); further, phlogopite, titanite, calcite, zircon and apatite. The quartz and feldspars sometimes also occur in the form of veins and small lumps in the main rock.

Anorthite-bearing rocks

Rocks of this composition, characterized above all by the paragenesis anorthite-zoisite (epidote), were found on the small islands of Krokøya and Purkholmen, near Abelvær, where they occur in a few flat lenses in a hornblende-biotite-bearing gneiss. They are light-colored, medium-grained, compact rocks. Now and then, parts of the rock mass may be slightly rose-colored, probably on account of a local concentration of manganese (thulite). The rocks are also distinguished by the absence of any potash-bearing constituent.

The following minerals have been found: basic plagioclase, diopsidic proxene, garnet, zoisite, clinozoisite, epidote, hornblende, quartz, calcite, titanite, zircon and apatite (Pl. II, fig. 1).

The plagioclase is anorthite, as determined by the refractive index Ng = 1.584, high relief, and relatively strong birefringence, giving an approximate composition Ab_5An_{95}. The mineral occrurs in xenoblastic crystals (up to 3 mm is size) which may contain numerous, small roundish grains of quartz. Grains of garnet and diopside have also been observed.

The diopsidic pyroxene is almost colorless in thin section. In one sample, these optical properties were measured: Ng = 1.713, Np = 1.684, Ng—Np = 0.029, $Z \wedge c = 40°$, corresponding to a diopside with about 30 per cent of Fe-silicate. In another specimen was found Ng = 1.730, which corresponds to a diopside with an approximate composition $Di_{45}He_{55}$.

The garnet occurs typically in chain-like narrow rims of minute, isotropic grains around larger crystals of anorthite, diopside and

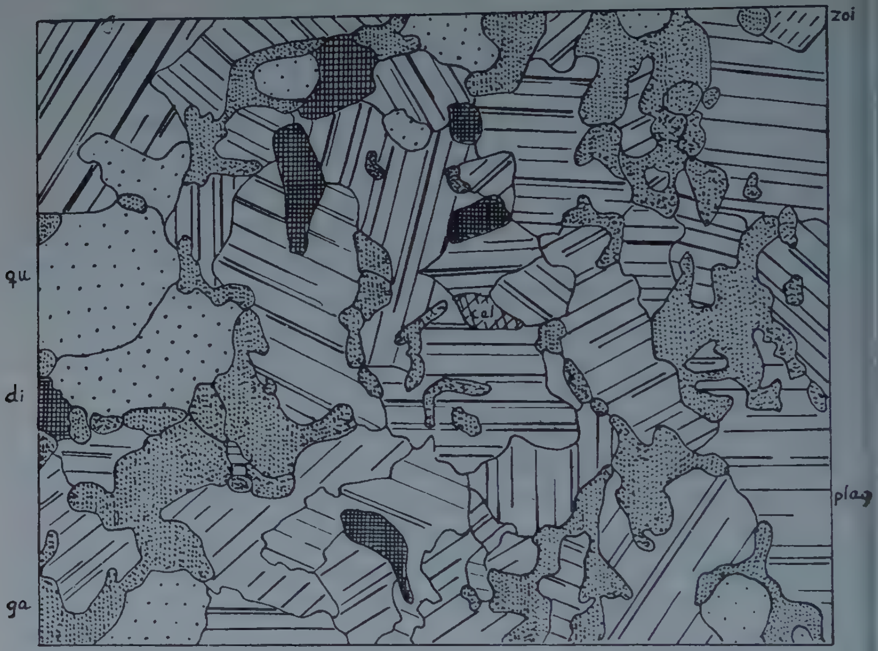

Fig. 6. Anorthite-grossularite-bearing lime silicate rock. From Krokøya near Abelvær. Drawing after photomicrograph. x 70.

quartz (Fig. 6). Megascopically, the mineral is yellowish brown in color. The index of refraction is N = 1.754, which is thought to correspond to a garnet with dominating grossularite molecule.

The zoisite usually forms aggregates of small prisms. The mineral, which is α-zoisite with $(+2V) =$ ca. 45°, is in immediate contact with anorthite, diopside and garnet.

The clinozoisite is found in up to 3 mm long, comparatively broad crystals, which may contain grains of anorthite and zoisite.

The epidote, forming small prisms, sometimes has inclusions of anorthite.

The hornblende, found in insignificant amounts in some thin sections, has a marked pleochroism, with Z deep green. The negative optic angle is about 60°.

Of the other minerals present, quartz, calcite and titanite are common, while zircon and apatite are rarely found. The calcite is in direct contact with anorthite.

Topaz-bearing lime silicate rock

This rock type was found in a road-cut near Kleven farm, at the head of Lyngen fjord, southwest of Namsos. The rock is greenish grey in color, medium-grained, and compact. The chief constituents are diopsidic pyroxene and a white mineral which appears to be topaz. In addition, scattered crystals of titanite and bluish-green apatite can be seen. Under the microscope, the diopsidic pyroxene frequently shows lamellar twinning. It is partly altered to an almost colorless amphibole. The topaz forms densely packed aggregates of small prisms which exhibit one perfect cleavage parallel to 001. The topaz is biaxial positive with $(+2V) = 60°$ approximately. The hardness is about 8. In addition to the minerals mentioned above a few grains of clinozoisite and traces of calcite are found.

Crystalline Limestone and Dolomite

These rocks, of which the crystalline limestone is the most widespread type, usually occur in close connection with members of the group of lime silicate gneiss. The marbles may appear as thin stripes or laminae in the gneiss, but also as thicker layers of great horizontal persistence. Very occasionally, the layers may attain a thickness of up to 50—100 m or more. In texture, the marbles are medium- to fine-grained rocks. The color varies from a grey or whitish grey (sometimes with a tinge of red) in the crystalline limestone, to a pure white in the dolomite-marble. Apart from the two carbonates, calcite and dolomite, the following minerals have been observed: diopside, cummingtonite, phlogopite, biotite, plagioclase, quartz, further tourmaline, zircon, apatite, pyrite, pyrrhotite and graphite.

Igneous Rocks

Volcanic Rocks

Amphibolitic rocks which are supposed to represent metamorphosed basaltic lavas have been found at several places in the basement region. These rocks may occur both as flake-like masses in the granite and granodiorite, and as narrower and broader zones within the non-plutonic rock system. They all are dark-colored, medium-grained, more or less foliated rocks, which have been completely recrystallized.

We may distinguish two rock types, which conform to the following mineral assemblages:

1. Hornblende-andesine.
2. Hornblende-oligoclase-clinozoisite-garnet.

1. This type is restricted to the northernmost part of the region. The chief minerals are hornblende and plagioclase.

The hornblende is black in specimen. Under the microscope it is distinctly pleochroic, with X pale yellow, Y greenish yellow to brown, Z greenish brown. In a sample collected from the western slope of the mountain of Høgråna, east of Rørvik, these optical properties were determined: $Ng = 1.690$, $Np = 1.670$, $Ng—Np = 0.020$, $Z \wedge c = 17°$, $(—2V) =$ ca. 85°. In another sample taken from a road-cut near Fredrikmoen farm about 2 km southeast of Gravvik church, were measured: $Ng = 1.679$, $Np = 1.660$, $Ng—Np = 0.019$, $Z \wedge c = 18°$.

The plagioclase is intermediate-basic andesine (An_{40-50}). It always shows twinning according to several laws.

Accessory minerals are reddish-brown, strongly pleochroic biotite, colorless diopsidic pyroxene (found as small patches in the hornblende), titanite, apatite and magnetite.

2. This rock type is comparatively abundant in the southern districts of the basement region.

The hornblende, which is the main constituent, is greenish black in specimen. In thin section, it is distinctly pleochroic, with X yellowish green, Z bluish green.

The plagioclase is intermediate oligoclase. Twinning is commonly seen.

The clinozoisite occurs in small prisms which are evenly distributed throughout the rock.

The garnet is present in varying quantities. Locally, the individual crystals may attain a size of up to 1.5 cm across. The color is a brownish red.

Accessory constituents are chlorite, quartz, titanite, apatite, pyrite and calcite.

Plutonic Rocks

Basic and Ultrabasic Plutonic Rocks.

These rocks comprise more or less metamorphosed representatives of peridotitic, noritic, and hyperitic types, the term hyperite being used in the sense defined by JOHANNSEN (1937, III, p. 238). The rocks form small lentoid bodies in the supracrustal complex.

Serpentine and Allied Rocks

Concerning the members of the peridotite family, they are evidently always completely serpentinized. The mineral composition may be: antigorite, talc and magnesite, with chrysotile and iron ore in subordinate amounts. By further alteration, the serpentine may pass into a rock consisting chiefly of talc and magnesite. A rock of this character (soapstone), forming a lentoid body about 50 by 250 m in size, was found in the gneiss zone on the northeastern slope of the mountain of Kjøringsvassfjell, west of Kongsmoen, in the Foldereid district.

Norite

Megascopically, the norite is a brownish-grey, medium-grained, massive rock, showing spheroidal weathering. In a sample collected along the road, 300 m east of Fossenget farm, southeast of Gravvik church, the following minerals were observed: plagioclase, orthorhombic pyroxene, brown hornblende, biotite and iron ore.

The plagioclase is faintly brownish in thin section, owing to innumerable dustlike inclusions. Polysynthetic twinning on the albite and pericline laws occurs. The composition of the plagioclase is about An_{65} ($Ng = 1.569$).

The orthorhombic pyroxene is weakly pleochroic under the microscope. It has abundant Schiller inclusions. The mineral is biaxial negative (large optic angle) with $Ng = 1.702$, $Np = 1.690$, $Ng—Np = 0.012$, which in the diagram of WINCHELL (p. 218) correspond to a hypersthene with about 24 per cent of Fe-silicate. The pyroxene is obviously in the process of replacement by hornblende.

The hornblende has a peculiar pleochroism: X very pale yellow, Y = Z pale brown. The following optical properties were determined: $Ng = 1.663$, $Np = 1.643$, $Ng—Np = 0.020$, $Z \wedge c = 19°$, $(—2V) =$ ca. 85°. The hornblende occurs partly in larger prismatic grains which may be filled with inclusions of iron ore (inherited from the pyroxene), partly in minute needle-like individuals.

Accessory constituents are reddish-brown biotite, magnetite and ilmenite.

Olivine Hyperite

The olivine hyperite is a dark-colored, medium-grained, massive rock. It shows spheroidal weathering. In a sample collected from a small lens-shaped mass just south of Lurudal railway station (16 km southeast of Grong church), the following primary minerals were found: plagioclase, olivine, augite, hypersthene, biotite, orthoclase, apatite and iron ore. Secondary minerals are amphibole, garnet and orthorhombic pyroxene, all of which may occur in the reaction zones between the plagioclase and the dark primary constituents. The texture is subophitic.

Primary minerals. The plagioclase is labradorite. The mineral forms lath-shaped individuals, which are slightly clouded by a brown dust. The plagioclase is well twinned, mainly according to the albite law.

The olivine occurs in hypidiomorphic or xenomorphic crystals.

The augite is interstitial to plagioclase. Several adjacent grains may have the same optic orientation. The mineral is biaxial positive, with $(+2V) =$ ca. $25°$, and $Z' \wedge c = 30°$ (subcalcic augite?). The optic plane is parallel to 010.

The hypersthene forms variously sized, angular crystals. The pleochroism is distinct with X brownish red. The hypersthene is sometimes found as a thin mantle-like rim about the grains of olivine. Several small (corroded) grains of olivine may also occur as poikilitic inclusions in the hypersthene.

Accessory constituents are reddish-brown, strongly pleochroic biotite, orthoclase, apatite, and iron ore (magnetite, ilmenite?). The orthoclase is interstitial to plagioclase.

Secondary minerals. Reaction rims are found between the plagioclase and the following dark primary constituents: olivine, biotite, hypersthene and iron ore, while they are usually absent around the grains of augite. The reaction products are green, weakly pleochroic, fibrous amphibole; colorless, fibrous orthopyroxene; and garnet. Double reaction rims may be found around the grains of olivine, and consist of an inner, thin zone of orthopyroxene towards the olivine and an outer, broader zone of amphibole (with or without garnet) towards the plagioclase. The garnet seems in most cases to be concentrated near the inner border of the amphibole zone.

Gabbro, sensu stricto

Rocks of this kind have not as yet been observed by the present writer. In this connection, however, it seems worth mentioning the location of a mass of basic plutonic rocks scattered over several smaller islands in the coastal tract WNW of Namsos. Unfortunately, the writer has not had the opportunity of visiting this locality, and as the information available from the older geological literature is somewhat incomplete, no further can be said on this subject until additional data can be obtained.

Acid-Intermediate Plutonic Rocks

Plutonic masses composed essentially of granite and granodiorite occupy vast expanses of the basement region. The rocks may be divided into three groups:

1. *Granite, granodiorite, etc.*

These rocks, among which are found representatives of various plutonic families, are intimately connected in the field. However, granite and granodiorite predominate. Occasionally, quarts-dioritic, syenodioritic, or dioritic rock types are found. The rocks might also be subdivided, on the basis of the femic constituents, into biotite-bearing, hornblende-biotite-bearing and hornblende-pyroxene-biotite-bearing types. In addition, a biotite-muscovite-bearing subtype of the common type of biotite granite may occur.

The said plutonic rocks mostly have a distinctly foliated or gneissic appearance (in the writer's opinion a primary structural feature), simultaneously as they often exhibit a well-defined lineation. Inclusions of country rocks, flake-like masses which may show strong deformation and folding phenomena, are usually oriented parallel to the planar structure of the granite and granodiorite (Fig. 7). Unoriented xenolithic masses are less commonly found (Fig. 8).

The rocks are generally medium-grained. Not infrequently, they may exhibit a porphyritic texture, with tabular feldspar crystals lying in a finer-grained matrix. The color of the rocks is varying shades of grey, often with a tinge of red.

The following minerals have been found: quartz, acid plagioclase, potash feldspar, biotite, hornblende, monoclinic pyroxene; further, muscovite, garnet, epidote and orthite-epidote, titanite, zircon, apatite, magnetite and pyrite.

The quartz is present in varying amounts. It always shows undulatory extinction.

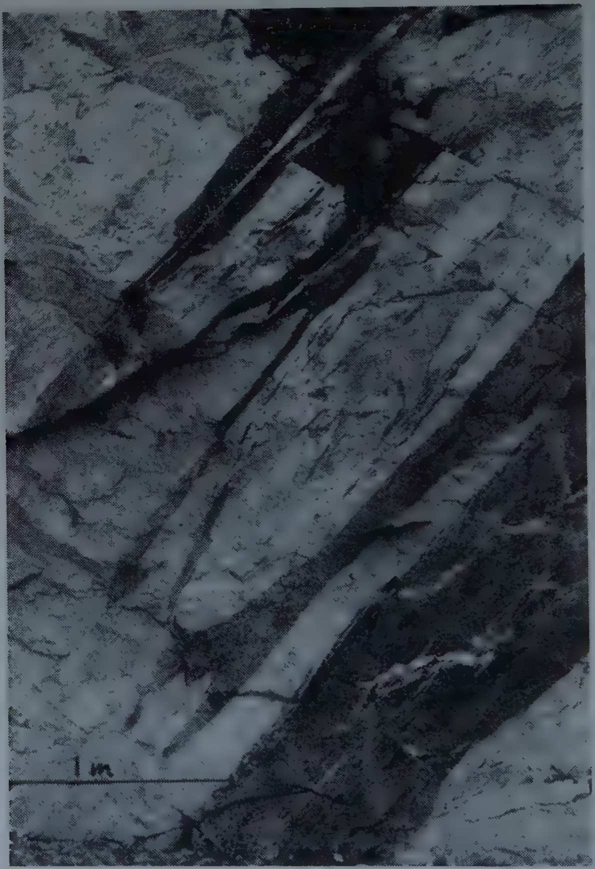

Fig. 7. Steeply dipping, isoclinally folded flakelike inclusion of amphibolitic rock (metabasalt?) in foliated biotite granite. Road-cut to the north of the farm Anskaret, on the southeastern side of Lyngen fjord, southwest of Namsos.

The plagioclase is intermediate to basic oligoclase (An_{20-30}). Polysynthetic twinning on the albite and pericline laws is common. Myrmecite in small individuals occurs in most thin sections.

The potash feldspar is microcline, partly also microcline microperthite. Sometimes, the perthite structure may be almost submicroscopic, with lamellae of acid plagioclase down to 1 by 10μ in size. Larger tabular crystals may show simple twinning on the Carlsbad

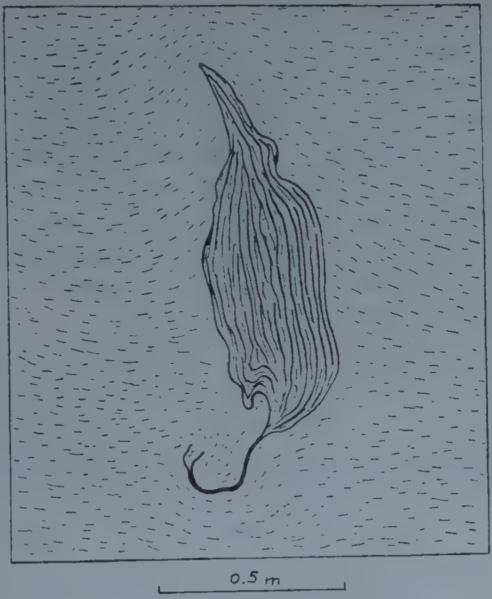

Fig. 8. Unoriented flat inclusion of hornblende-biotite-bearing lime silicate gneiss in foliated biotite granite. From the northern slope of the mountain of Kjøringsvassfjell, west of Kongsmoen.

law. The potash feldspar may also be found as optically oriented insets in the plagioclase.

The biotite has very strong pleochroism, with X pale brown, Y = Z dark brown to almost opaque. Inclusions of zircon are surrounded by the usual pleochroic halos.

The hornblende is black in specimen. The mineral has small optic angle (2V over X = 10—60°, often giving the impression of an almost uniaxial mineral), high indices of refraction (Ng = 1.690—1.715), and distinct green to dark-green pleochroism. These optical properties evidently place the hornblende in a specific subclass of the amphiboles, the hastingsites, which are characterized crystallochemically by 2 Al in Si-position (suggestive of a rather high temperature of formation. See, for instance, summary in FOSLIE, 1945).

The monoclinic pyroxene is dark green to greenish black by incident light. Under the microscope, it is pale green and weakly pleochroic. The mineral is biaxial positive with (+2V) = ca. 60°. $Z \wedge c$ =

47°—50°. The pyroxene, which probably has a composition approaching that of augite, may occur both as independent crystals and in parallel growth with hornblende.

The muscovite is mostly absent.

The garnet is a fairly common minor constituent of the granitic members of the plutonic association concerned, while it is usually absent in the granodioritic types. The garnet occurs in small, rounded grains, which are mostly less than 0.5 mm in diameter.

Epidote and orthite-epidote. The appearance of these minerals seems to be locally conditioned.

Other minor constituents are titanite, zircon, apatite, pyrite and magnetite.

Younger pegmatite. This rock is a light-colored acid pegmatite, which in the form of narrow dikes and granite-filled shears cuts the structures of the slightly older plutons of granite and granodiorite. The dikes are short (generally less than 50 m in length), steeply dipping bodies, which have a thickness ranging from about 1 dm to 1—1.5 m. Occasionally, the dikes may exhibit a zoned structure. In this case, the feldspars are concentrated along the walls, while most of the quartz forms the core. The chief minerals are quartz, microcline or microcline microperthite, and oligoclase. Graphic intergrowths of microcline and quartz are frequently observed. Biotite is the common dark mineral, while hornblende is rarely met with. Orthite-epidote may form comparatively large crystals in some dikes. Muscovite is entirely absent.

Regarding the origin of these dikes and granite-filled shears, they were probably formed during a late phase in the consolidation of the acid plutonic masses. The process may be followed step by step, from the first disturbances of the planar structure along small flexures in the main body, to the appearance of the larger dikes, indicating a gradual dilatation of the earlier fractures into which the liquid still remaining in the pluton was forced to move.

2. *Granite*

The members of this group of acid intrusives are fine- to medium-grained granitic rocks, which exhibit distinct planar and/or linear structures. The color is a light reddish grey. Both porphyritic and nonporphyritic rock types have been encountered. The porphyritic

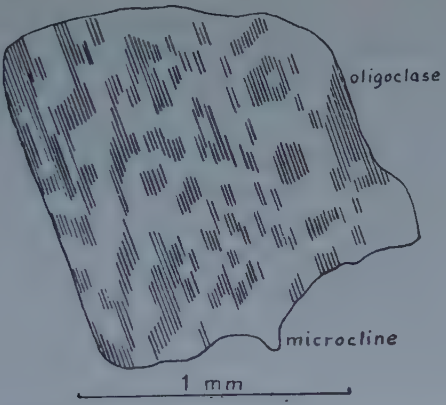

Fig. 9. Feldspar phenocryst in fine-grained, porphyritic granite. 3 km east of Bodom church, east-southeast of Steinkjer.

(and predominant) type has numerous, small feldpar phenocrysts (tabular crystals attaining a maximum length of 4—5 mm), which are embedded in a fine-grained matrix of feldspar and quartz. The feldspar of the phenocrysts is usually a perthitelike type (Fig. 9), less commonly microcline or oligoclase. The feldspar of the fine-grained matrix is microcline and oligoclase. Biotite is present in small quantities. In addition to these minerals may be found accessory amounts of garnet, muscovite, epidote, titanite, zircon, apatite, and magnetite.

This granite occupies the greater part of the anticlinal region south of the Snåsa syncline. Presumably, the granite finds its continuation eastwards into the area of acid plutonic rocks between the eastern termination of the Snåsa syncline and the district of Liene, here corresponding to the "porphyry" of FOSLIE.

3. *Granodiorite, in part quartz-diorite*

These rocks are considered as the youngest members of the whole series of acid plutonic associations. They are light-grey, weakly to moderately foliated rocks, usually medium-grained, but may locally develop fine-grained (aplitic) or pegmatitic textures. The rocks differ from the types described above in that, in addition to biotite, they contain muscovite in fairly large quantities.

The quartz, which is present in abundance, often shows strong undulatory extinction.

The plagioclase is oligoclase (An_{20} to An_{30}). Polysynthetic twinning is common. The plagioclase crystals may also be distinctly zoned, frequently in a complex oscillatory mode of zonal growth. In a sample collected from the island of Kvaløy, in the Vikna district, the following variation in the An content (from the core towards the border) was observed: $An_{27} \longrightarrow An_{31} \longrightarrow An_{23} \longrightarrow An_{27} \longrightarrow An_{21}$. Myrmecite is present in small grains.

The potash feldspar is usually microcline, more rarely microcline microperthite.

The biotite occurs in small flakes. It is brown in color, and strongly pleochroic.

The muscovite forms relatively large laths, which are oriented in a common direction. The mineral is often found in parallel growth with biotite.

In accessory amounts may occur epidote or clinozoisite (minute prisms, partly with core of orthite-epidote); rarely garnet; further, zircon and apatite.

PETROLOGY

Nonplutonic Rocks

The presence of regionally metamorphosed sediments and volcanics has been demonstrated. Texturally, the original supracrustal rocks have been completely reconstituted. On the other hand traces of primary structures (bedding, sometimes cross-bedding) may be found in the derivatives of several types of sediments, even at high grades of metamorphism.

Among the metasediments, gneissic rocks predominate. Most of the gneisses probably represent metamorphosed arenaceous sediments, while certain types of lime silicate gneiss may have originated from marly sediments. Other rock types, occurring in relatively small quantities, are quartzite, quartz schist, mica schist, and crystalline limestone and dolomite. It might seem permissible to conclude, therefore, that the principal types within the old province of sedimentation had the character of arenaceous and mixed sediments, such as arkosic sand, calcareous sand, clayey sand, marly sand, marl, etc.

This lithological picture accords with the writer's interpretation regarding the genesis of the metasediments. As a consequence of intense orogenic movements, the geosynclinal rocks were pressed down to lower levels in the earth's crust. Thereby, the temperature was sufficiently elevated in the original sediments to cause the development of certain rock types which are characteristic of high-metamorphic terrains.

Although it is far from the intention of the present writer to attempt to invalidate the role of metasomatism in petrogenesis, caution should nevertheless be exercised in claiming a rock, e. g., a gneiss of whatever composition, to have been formed under the influence of metasomatic agents. It is also the writer's field geological experience that changes due to metasomatism have apparently been confined to the narrow border zones adjoining the plutons of granite and granodiorite. The boundaries between these plutons and the regionally metamorphosed country rocks may be gradational, suggesting a "lit-par-lit" intrusion of granitic magma into the contact zone parallel to the foliation of the wall rock. The host rock itself may bear the imprint of metasomatic influence, caused by the fluids expelled from the consolidating granitic magma. In this manner may be explained the appearance of light-colored quartz-feldspar-rich streaks or veins, and the formation of isolated feldspar porphyroblasts (augen) in the rocks of the border zones. Diopside has evidently been chemically unstable in this outward flow of granitic emanations, having, therefore, to a great extent been converted to hornblende. Similarly, anthophyllite or cummingtonite would react with the introduced granitic juice to produce biotite, while cyanite would be transformed to muscovite.

Lastly, a short comment on the volcanic rocks. Only basic types have been found. These rocks are supposed to represent strongly metamorphosed basaltic lavas. According to their present structure and mineral composition they should be termed amphibolites.

Plutonic Rocks

In the writer's opinion, these all are magmatically derived rocks, which have crystallized in the earth's crust under the appropriate P. T.-conditions to achieve a plutonic aspect. This applies both to the basic (and ultrabasic), and to the acid rock types. The former group includes noritic and hyperitic types. The hyperites in their geological mode of occurrence and in their petrography show great analogies to the hyperites of Sørlandet (southernmost Norway), the more so as the latter are in the same manner associated with rocks of noritic composition (BUGGE, 1943). Further, GJELSVIK (1952) has in a recent paper given an elaborate description of similar rocks in the district of Sunnmøre, on the west coast of southern Norway.

The interpretation of the acid plutonic rocks as being of magmatic origin is perhaps a somewhat orthodox view. Nevertheless, the writer considers the great majority of the granites and granodiorites to have developed in this way. Concerning the formation of the granitic magmas, the writer agrees with those petrologists who call attention to a differential anatexis of rocks of varying composition at the base of the earth's crust as a possible cause. The more or less heterogeneous character of the granites and granodiorites in many denuded regions of old age (including the region under consideration) might tentatively be explained by the hypothesis hinted at above, the often numerous xenolithic masses being interpreted as the remainders of a pre-existent rock system that was not completely re-fused. An alternative explanation of this heterogeneity would be that the inclusions were picked up by a homogeneous granitic magma, when squeezing its way through the essentially solid country rocks.

NOTE ON THE MINERAL FACIES

With a few exceptions, the rocks of the basement complex originated under physical conditions which correspond to the requirements of the amphibolite facies, this concept being used in accordance to the definition given by TURNER and VERHOOGEN (1951). Thus, the gabbro facies, as typified by certain basic plutonic rocks (norite, olivine hyperite), is only locally developed. While the majority of the plutonic igneous rocks (mainly granite and granodiorite) belong to the high-temperature portion of the amphibolite facies, there is a moderate fall in the metamorphic grade of the nonplutonic rocks when advancing from the northernmost districts of the basement region towards the south and southeast, but still the grade of metamorphism lies well within the limits of the amphibolite facies.

It appears from the description of the metasediments that in micaceous gneisses of appropriate composition, potash feldspar (microcline) may sometimes occur in stable combination with sillimanite, cordierite and almandite. On the other hand, potash feldspar has never been found in paragenesis with anthophyllite or cummingtonite. Using the facies classification of TURNER and VERHOOGEN (op. cit.), the said gneisses should be placed in the high-temperature sillimanite-almandite subfacies of the amphibolite facies. In the present nonplutonic rocks, orthorhombic pyroxene has never been observed. This feature, plus the relatively common appearance of cummingtonite, indicate a metamorphic temperature not sufficiently high to permit the crystallization of magnesian pyroxene at the expense of the analogous hydroxyl-bearing minerals.

As already mentioned, there is a moderate fall in the metamophic grade of the nonplutonic rocks when proceeding from the northernmost districts of the basement region towards the south and southeast. Thus, there is every indication that the bulk of the nonplutonic rocks which appear in the districts to the east and southeast of Folden fjord, originated under pressure-temperature conditions characteristic of the staurolite-cyanite subfacies of the amphibolite facies, as defined by TURNER and VERHOOGEN (op. cit.). Only locally, in the proximity to the granitic bodies, may the nonplutonic rocks attain a higher grade of metamorphism, conforming to the sillimanite-almandite subfacies, simultaneously as a vein structure (resembling the structures found in partially re-fused rocks) may appear in metasediments of appropriate composition (Fig. 3). In other places, possibly influenced by relatively rapidly falling temperatures, the rate of the metamorphic processes may have been sufficiently reduced to cause the development of mineral associations indicative of a state of disequilibrium.

TECTONICS

The map, Pl. III, which gives a general view of the petrography and tectonics of the basement region, obviously presents the picture of an old, deeply denuded mountain chain. The trend of this orogenic zone seems to have been about N 65° E. However, important deviations from the main trend can be seen in the districts southeast of Folden fjord, where a foliation on N-S to NW-SE axes, intersecting the main direction of folding at almost right angles, has been developed.

It is evident from the map that complex folding movements must have taken place in connection with a mighty upsurge of granitic magmas (concordant, syntectonic acid intrusives). During this demonstration of intense plutonic activity, the geosynclinal zone was split into smaller parts, represented by strongly contorted belts of metamorphosed supracrustal rocks. The granitic plutonic rocks appear in massifs of varying shape and size: they may form comparatively small, highly elongated bodies, as in the districts north of Folden fjord, or they may appear in large, rather irregularly terminated and intricately constructed massifs, as in the vast area of granite and granodiorite southeast of the same fjord.

THE CAMBRO-SILURIAN ROCK SYSTEM

This rock system falls into three separate parts: — (1) The narrow, strongly compressed Snåsa syncline, with sedimentary and igneous rocks of low metamorphic grade. (2) The relatively broad Bindal syncline, with medium- to high-grade metamorphic sedimentary and volcanic rocks. In addition, granite and granodiorite occupy an essential portion of the syncline. (3) The Leka district, with basic and ultrabasic plutonic rocks underlying a series of steeply dipping layers of conglomerate, feldspathic sandstone, and phyllite.

Regarding the Snåsa syncline, only a brief account of the geology of this region will be given. The description is chiefly based on the writer's own, fairly random observations within the syncline, while a few data have been taken from the above-mentioned paper of H. Carstens (1955).

The Snåsa Syncline

The rocks belong to two stratigraphical-tectonic units: an old complex of metamorphosed supracrustals and acid intrusives, and a younger series of conglomerate and sandstone. A map of the syncline is seen in Fig. 10.

THE OLD COMPLEX

Sedimentary Rocks

Quartzite Conglomerate

Conglomerates appear to be of rare occurence within the old complex. Up to the present, only one outcrop of a rock of this kind has been found. The locality in question is situated about 2 km due south of

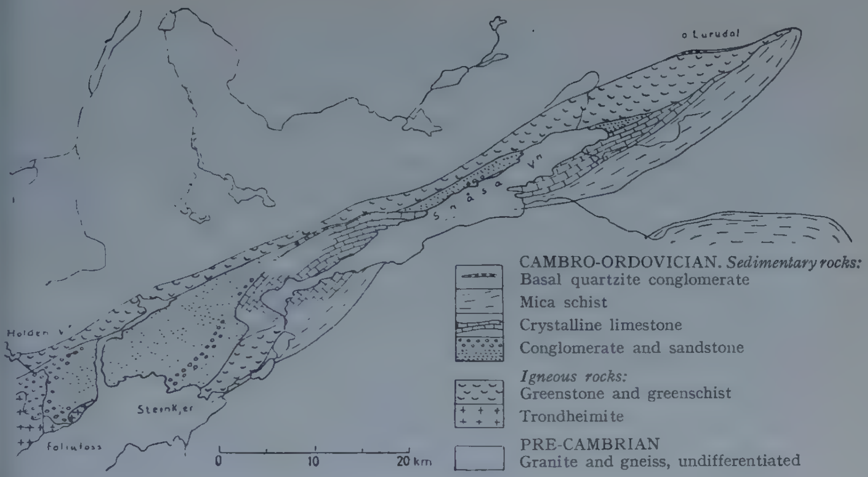
o Lurudal
Snåsavn
Holden
Steinkjer
Follafoss
0
10
20 km
CAMBRO-ORDOVICIAN. *Sedimentary rocks:*
Basal quartzite conglomerate
Mica schist
Crystalline limestone
Conglomerate and sandstone
Igneous rocks:
Greenstone and greenschist
Trondheimite
PRE-CAMBRIAN
Granite and gneiss, undifferentiated

Fig. 10. Geological map of the Snåsa syncline.

Lurudal railway station, where the conglomerate appears as a thin layer (less than 10 m thick) at the base of the Cambro-Ordovician supracrustal formations. Owing to intense folding pressure, the original cobbles, composed exclusively of a finer-grained, light-grey quartzite, have been almost completely rolled out, and now resemble flat, discus-shaped bodies.

Quartzite

Quartzite may be found as layers of varying thickness near the base of the supracrustal series. It is a dark-grey rock consisting mainly of quartz and muscovite.

Mica Schist

Mica schist forms a relatively wide zone along most of the southern flank of the Snåsa syncline. The zone, after having been much reduced in width, continues along the northeastern boundary of the syncline, where it finally disappears a little west of Lurudal railway station.

The mica schist is a grey to greenish-grey rock. The chief minerals are: quartz, muscovite and chlorite. In addition, calcite may sometimes occur in fairly large quantities. Biotite is rather uncommon, but it is probable that some of the chlorite may be diaphthoretic after biotite. Garnet has been found in certain varieties of the mica schist occurring near the base of the supracrustal series.

Crystalline Limestone

As appears from the map, Fig. 10, crystalline limestone occupies a greater part of the syncline. From a little west of Lake Snåsa vatn, this rock extends for about 60 km, the zone tapering towards the east.

The limestone is usually grey to darker-grey in color. In addition to calcite, may be found subordinate amounts of quartz, muscovite, talc and graphite. Of particular interest is the finding of fossil remains in the Snåsa limestone, as reported by H. CARSTENS.

Igneous Rocks

Volcanic Rocks

Greenstone and Greenschist. Amphibolite

Basic volcanic rocks of low metamorphic grade form a continuous belt of varying breadth along the northern flank of the syncline. A similar belt, but of much smaller dimensions, occurs southwest of the western end of Lake Snåsa vatn. The bulk of these rocks were probably basic lavas. Here and there may be found intercalated beds of crystalline limestone.

Greenstone and greenschist are the common rock types. The minerals are: actinolitic amphibole, albite, clinozoisite (or epidote), chlorite and calcite; further, biotite, quartz and titanite in accessory quantities.

Locally, in the contact zones around intrusive masses of trondheimite, the greenstone and greenschist may have been transformed into a dark-colored amphibolitic rock. The amphibolite consists of abundant hornblende (dark green to greenish black in specimen), minor amounts of albite and epidote, scales of brown biotite, and sporadic grains of calcite.

Quartz-keratophyre

According to H. CARSTENS, metamorphosed acid lavas and agglomerates (often with well-preserved primary structures) are common rock types in the higher stratigraphical parts of the volcanic formation of the Snåsa syncline and its southwesterly continuation.

Intrusive Rocks

Saussurite Gabbro. Diorite

In the tract Malm—Folla vatn, a narrow, ENE-WSW directed zone of saussuritized gabbroic and dioritic rocks occurs. The rocks are intrusive into the northern belt of greenstone and greenschist.

Trondheimite Aplite and Trondheimite Porphyrite

Sill-like intrusions of these rock types have been found at several places within the old complex. They are light-colored, somewhat foliated rocks. Both aplitic and porphyritic types occur, the latter with tabular albite phenocrysts (up to 2 mm in length) set in a very fine-grained groundmass composed essentially of albite and quartz. The other minerals are biotite, epidote and chlorite (secondary after biotite).

Trondheimite

A larger massif of trondheimite lies south and southwest of the low mountain of Malbuheia, at the western end of the Snåsa syncline. The trondheimite is distinctly younger than the greenstone complex. This fact can be demonstrated in road-cuts ENE of Follafoss hydro-electrical power station. A much smaller body of the same rock type is found a little farther northeast, in the area between Malm and Hjellebotn.

The trondheimite, which structurally and mineralogically may be parallelled with the "protogine granites" of the Trondheim region, is a light-grey, medium-grained rock with a pronounced linear structure, while the foliation is weakly developed. The gathering of the quartz into small, oval masses (up to 1 cm in length) gives the rock a structure which to some extent resembles that of the so-called "quartz augen gneiss" of the Bergen area.

Albite and quartz are the chief minerals. Other constituents are biotite, muscovite and epidote. The feldspar individuals, showing twinning on the albite and pericline laws (often broad lamellae), may be filled with minute grains of clinozoisite and flakes of muscovite. The biotite is brown, and strongly pleochroic. Accessory minerals are titanite, zircon and apatite.

THE YOUNGER SERIES

Conglomerate and sandstone form a zone of highly varying width in the Snåsa syncline.

The conglomerate consists mainly of well-worn fragments of granitic rocks. Occasionally, cobbles of trondheimite, greenstone, saussurite gabbro and crystalline limestone are found. As a result of strong, local deformation, the cobbles may have been more or less flattened and elongated.

The sandstone is a grey or greenish-grey rock. The secondary foliation, arisen through the parallel orientation of muscovite and chlorite, appears in most cases to coincide with the bedding of the rock. The other minerals usually present are quartz, albite and epidote, while biotite and a pale green amphibole are less common.

NOTE ON THE MINERAL FACIES

The greater part of the rocks of the Snåsa syncline were probably formed under the physical conditions of the biotite-chlorite subfacies of the greenschist facies, as defined by TURNER and VERHOOGEN (1951). Locally, however, there are indications that a grade of metamorphism corresponding to the albite-epidote-amphibolite facies (TURNER and VERHOOGEN, op. cit.) has been reached (the appearance of garnet (almandite) in certain layers of the mica schist immediately overlying the basement complex, and evidence of contact metamorphism around intrusions of trondheimite in the greenschist and greenstone). Subsequent to the main stage of regional metamorphism, during a period of falling temperature, a readjustment of the rocks to the new physical conditions took place. As a consequence of this retrogressive metamorphism, the biotite has in many cases been converted to chlorite, the resulting rock thus conforming mineralogically to the muscovite-chlorite subfacies of the greenschist facies.

STRATIGRAPHY AND TECTONICS

The development of the geosyncline was probably initiated in the Cambrian with the deposition of thin, non-persistent beds of conglomerate and sandstone, which were later overlain by a thick succession of pelitic sediments. In this connection should be mentioned the almost complete absence of mica schist along the northern flank of the Snåsa syncline, a distinctive feature which cannot be tectonically conditioned (lack of evidence of thrust or fault movements along the junction against the basement complex; alternation between layers of quartzite, quartz schist, mica schist, and greenstone at several places along the same junction, indicating that the observed boundary situation is an unconformity). The large masses of crystalline limestone which occur within the syncline very likely date from the Ordovician. A similar age may also be suggested for the metamorphic derivatives of basic igneous rocks (greenstone, etc.) found within the syncline. Igneous rocks of this character are known from various other parts of the Caledonian chain, indicating widespread volcanic activity during the Skiddavian epoch with the pouring out of principally basic lavas and pyroclastic material. Later, the supracrustal rocks were injected by magmas of trondheimitic composition.

In the following orogenic phase, possibly identical with the Trondheim disturbance, which is assumed to have taken place at the transition interval between the Skiddavian and Llanvirnian epochs (HOLTEDAHL, 1920), the stratified rocks were tilted and perhaps slightly folded and metamorphosed. At the same time, parts of the geosyncline were elevated above sea level. There is reason to believe that the coarse sediments of the younger series of the Snåsa syncline began to accumulate on the denuded old complex shortly after the regression had ceased and the sea again transgressed the land surface. Thus, admitting no great break between the two rock systems, the younger series may tentatively be correlated with the lower part of the Lower Hovin series of the Trondheim region.

In a recent paper, VOGT (1945) has suggested that the conglomerates and sandstones occurring in the Malbuheia district, west of Steinkjer, overlie pre-Cambrian rocks. In this assumption the writer cannot agree. On the contrary, it must be considered a well-established fact that the said conglomerates and sandstones rest on unquestionably Caledonian rocks.

Finally, the two rock systems were folded and strongly deformed. In most cases, the strata seem to be right-side-up, but they may also be overturned. Tectonic disturbances due to thrust movements have, as stated above, not been observed within the Snåsa syncline.

The Bindal Syncline

The Bindal syncline may be defined as the southwesternmost part of the imposing Nordland synclinorium of northern Norway. Both metasediments and metavolcanics occur. The major portion of the syncline is, however, occupied by a large, N-S oriented, elongated mass of granite and granodiorite, known as the Bindal granite massif.

Sedimentary Rocks

Quartzite and Quartz Schist

These rocks occur as thin layers in the zones of mica schist and in the zone of metamorphosed acid lavas.

The rocks are grey in coloring. Common minerals, other than quartz, are muscovite, biotite and oligoclase. Possible components of the quartz schist are epidote and calcite.

Mica Schist

Two different zones of mica schist occur: (1) a lower zone which is in immediate contact with the basement complex, and (2) an upper zone which is detached from the former by an almost continuous belt of volcanic rocks. The two zones of mica schist will be treated separately.

(1) This zone extends for over 50 km in a north-south direction along the southwestern flank of the Bindal syncline, from the lower part of Sanddøldalen to Kongsmoen, at the head of Indre Folden fjord. At this point, the zone has been somewhat reduced in width, partly owing to changes of facies (medium- to high-grade metamorphic calcareous sediments gradually become the predominant rocks in the district north of Lake Øie vatn). From Kongsmoen, following the south side of Indre Folden fjord in a northwesterly direction, the zone of mica schist soon pinches out.

The mica schist is a grey to greenish-grey rock, which may have glandules and veins of quartz and/or calcite. There are two types of mica schist, one type having quartz and micas as the chief constituents, the other containing calcite and various lime silicates in addition.

The following minerals have been found: quartz, plagioclase, bio-

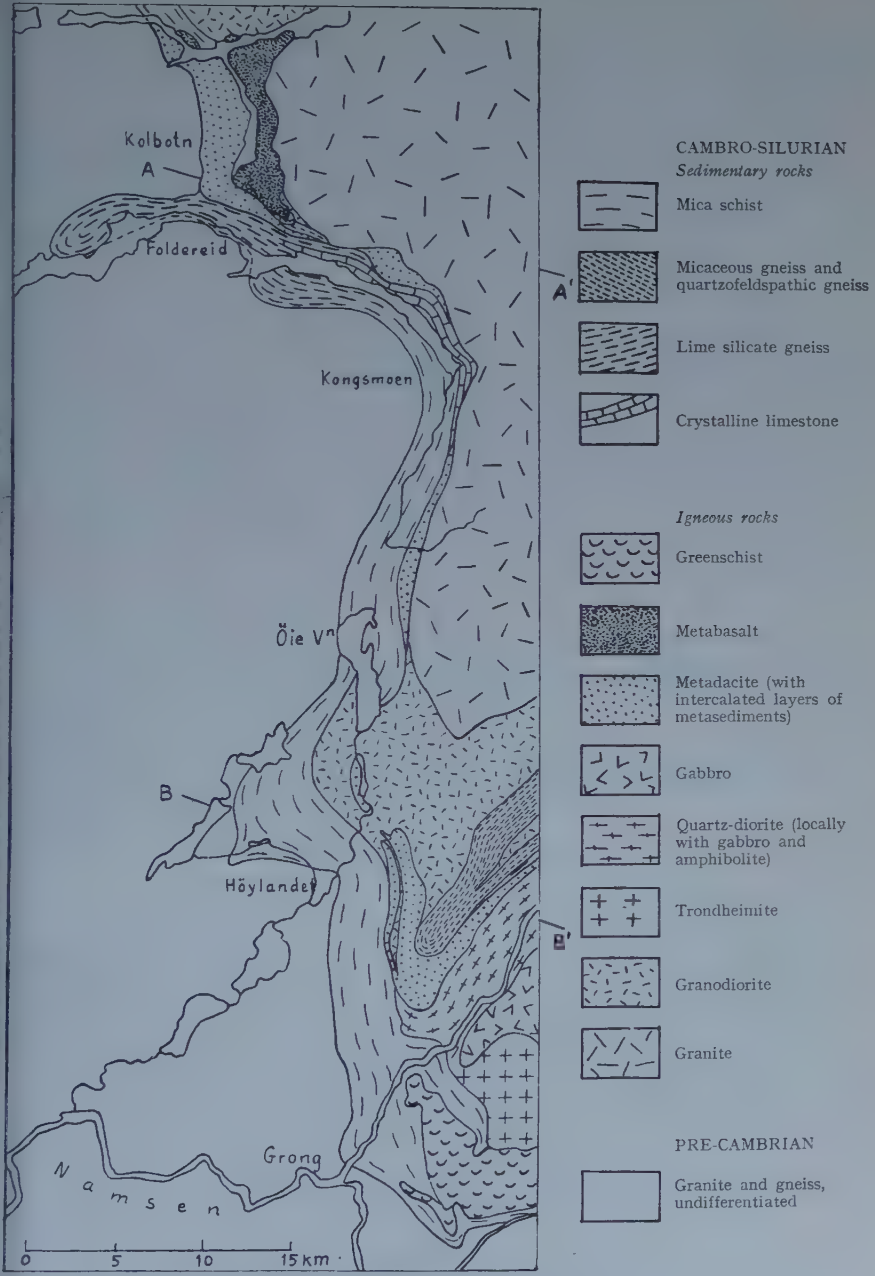

Fig. 11. Geological map of the southwestern part of the Bindal syncline.

tite, muscovite, cyanite, staurolite, almandite, hornblende, diopsidic pyroxene, zoisite, clinozoisite, epidote, calcite, tourmaline, titanite, zircon, apatite, pyrite and magnetite.

The quartz may exhibit strong undulatory extinction.

The plagioclase is present in highly varying quantities, and may also be entirely absent. The composition of the plagioclase lies between An_{20} and An_{40}. Twinning according to the albite and pericline laws is common, while zoning is very rarely seen.

The biotite occurs in relatively large individuals. Most of the biotite belongs to the common brown type. It has the pleochroism: X pale yellow, Y = Z brown to yellowish brown. Occasionally, a green type may be found. The pleochroism of the latter is X colorless, Y = Z pale green. The biotite often contains inclusions of zircon, to some extent also tiny prisms of clinozoisite or zoisite, all of which are surrounded by brown to dark-brown pleochroic halos.

The muscovite, when present, may be found in parallel growth with biotite.

The occurrence of cyanite, staurolite and almandite is mainly restricted to a narrow zone along the western boundary of the Bindal syncline between Grong railway station and Høylandet church. All three minerals are usually found as porphyroblasts. The cyanite may form prisms measuring up to 4—5 mm in length. The staurolite occurs as dark-reddish-brown, short-prismatic crystals attaining a size of up to 2—3 mm. In thin section, the mineral is distinctly pleochroic, with X colorless, Z golden yellow. The almandite is found in up to 1 cm large grains, which may contain inclusions of other minerals.

The hornblende may become an important constituent of rock types that are transitional to the lime silicate gneisses. The mineral occurs as long-prismatic, more or less poikiloblastic crystals measuring up to 0.5 cm, very occasionally up to 2 cm in length. The pleochroism is usually relatively strong, with X yellowish green, Y green, Z green to bluish green. The optic angle is large about X.

The diopsidic pyroxene, when rarely present, is colorless in thin section.

The zoisite and clinozoisite are common minor constituents of the calcite- and lime silicate-bearing types of the mica schist. Epidote, on the other hand, is of rare occurrence.

The content of calcite is subject to great variations.

Regarding the accessory minerals, tourmaline is present in most thin sections. The grains, tiny prisms measuring up to 0.5 mm in length, are strongly pleochroic, with X colorless, Z green to brownish green. Titanite is mostly absent, whereas zircon and apatite are common. Pyrite and magnetite form small grains in some thin sections.

(2) As referred to in brief above, this zone of mica schist is separated from the lower one by an almost continuous, arcuated belt of volcanic rocks, which also approximately marks the termination of the Bindal granite massif towards the west and south. The first traces of this upper zone of mica schist are found at the southern tip of the massif, where the strata are deflected from due north to east-west. The zone continues in a northeasterly direction, slowly increasing in width.

The mineral composition of the rock concerned may be quite simple, with quartz, muscovite and biotite as the chief constituents. In other cases, the mica schist is lime silicate-bearing, with a dark hornblende as the characteristic mineral.

Gneiss

Rocks with a typical gneiss structure, representing metamorphosed arenaceous and marly sediments, have been found at several places in the Bindal syncline. They may be classified under three heads: quartzofeldspathic gneiss, micaceous gneiss and lime silicate gneiss.

Quartzofeldspathic Gneiss

The gneiss may be subdivided into three types. Two of these types (Nos. 1 and 2 in the following description) occur in a 50 m thick zone on the western slope of the mountain of Holandsfjell, in the Foldereid district. The two types, which are intimately connected in the field, occur here as alternating darker and lighter bands and layers, thus indicating a primary bedding (Fig. 12). Associated with these originally clastic sediments may also be found intervening layers of metamorphosed acid lavas (Fig. 13). The third type, apparently occurring a little higher in the supracrustal series, forms a thin zone in the eastern part of the syncline.

1. This gneiss type is a grey, fine- to medium-grained rock composed chiefly of quartz and feldspars (microcline and oligoclase). Although

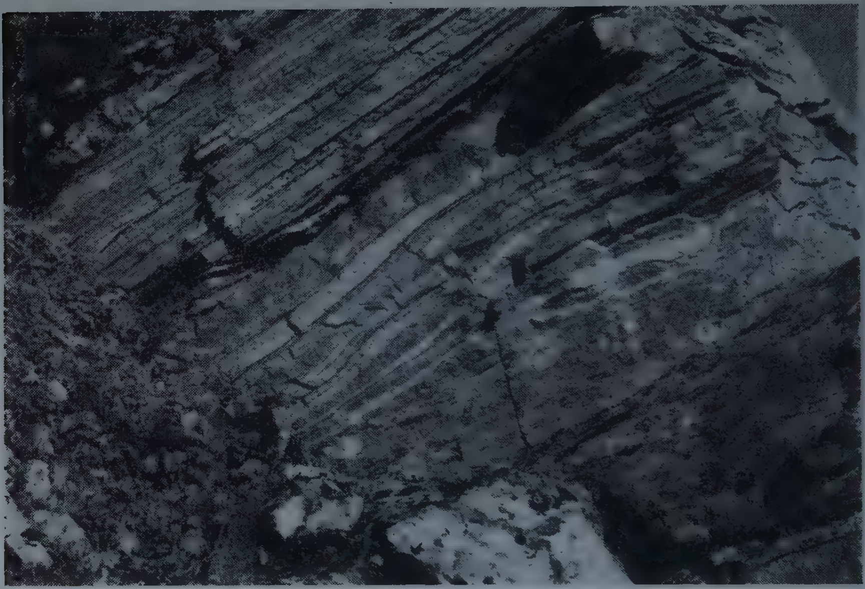

Fig. 12. Bedding in quartzofeldspathic gneiss.
From the western slope of the mountain of Holandsfjell
(684 m), east of Foldereid.

scattered, larger grains (of granitic composition) may have retained their clastic character, the rock is otherwise completely recrystallized. Additional constituent minerals are biotite and muscovite, which both occur in small flakes. The biotite has the pleochroism: X colorless, Y = Z pale brownish green, the latter color becoming yellowish brown around inclusions of zircon. Accessories are zircon, apatite and magnetite.

2. This gneiss is greenish grey in color. The grain size is usually less than 0.5 mm, while sporadic prisms of green amphibole may attain a size of up to 2.5 mm. These minerals have been found: quartz, plagioclase, amphibole, biotite, epidote, zircon and magnetite.

The quartz occurs in very small individuals.

The plagioclase is basic oligoclase. It occurs in small, angular grains.

The amphibole, which must be rather actinolitic in composition, has the pleochroism: X almost colorless, Z pale bluish green.

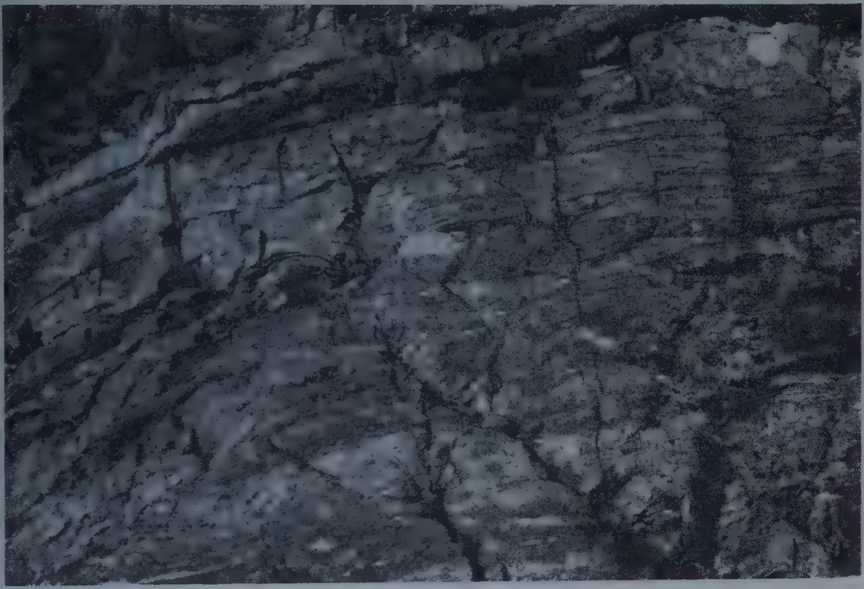

Fig. 13. Alternation between quartzofeldspathic gneiss (light grey) and metadacite (darker grey). From the western slope of the mountain of Holandsfjell (684 m), east of Foldereid.

The biotite is found in small flakes, which are evenly distributed throughout the rock. The pleochroism is: X colorless, Y = Z pale brownish green, becoming yellowish-brown around inclusions of zircon (or epidote).

The epidote (often with a core of orthite-epidote) has pale yellowish-green coloring. It occurs in small prisms varying in size between 0.1 and 0.5 mm.

3. This rock is a grey, fine-grained gneiss. Quartz and plagioclase are the main components. The plagioclase, which is basic oligoclase, forms small, subisometric grains. Other minerals are biotite, clinozoisite and garnet. The biotite has the pleochroism: X pale yellow, Y = Z brown. Inclusions of zircon are surrounded by intense pleochroic halos. The clinozoisite (frequently with a core of orthite-epidote) is found in small, slender prisms. The garnet (probably almandite) occurs in small, homogeneous grains with badly shaped crystal outlines. Accessory minerals are zircon, apatite and magnetite.

Micaceous Gneiss

Micaceous gneiss forms part of a relatively broad zone of metasediments on the southeast side of the Bindal granite massif. These metasediments, which also include quartzite, mica schist, quartzofeldspathic gneiss, lime silicate gneiss and crystalline limestone, have been invaded by innumerable, small and large sill-like bodies of foliated granite and granodiorite.

The micaceous gneiss is grey to darker grey, medium- to fine-grained, with a strongly defined secondary foliation. Quartz, oligoclase (An_{25-30}) and brown biotite are the main constituents. Other minerals which may be found are muscovite, garnet (probably almandite) and clinozoisite. Accessories are zircon, apatite, pyrite and magnetite.

Lime Silicate Gneiss

Larger occurrences of lime silicate-bearing gneissic rocks are mainly known from the district around the inner part of Indre Folden fjord.

The lime silicate gneisses may be divided into two groups: those with hornblende, and those with diopsidic pyroxene as essential dark constituents. With an increase in the amount of hornblende, the members of the former group pass into amphibolitic rocks. In these gneisses there may occur thin layers of mica schist (biotite- and almandite-bearing), as well as beds varying in thickness, of crystalline limestone and dolomite. The layers of almandite-biotite schist are always separated from the diopside gneiss by layers rich in hornblende (Fig. 14).

1. Hornblende-bearing gneiss (in part amphibolite).

The members of this group are dark-colored, medium-grained rocks. The foliation is usually distinct, being less conspicuous in the amphibolitic type. Hornblende and plagioclase are the chief components.

The hornblende is dark green to greenish black in specimen. Under the microscope, it is different shades of green. In a sample of a garnet-bearing amphibolite taken from a road-cut near Sjølstad, a little west of Foldereid, the following optical properties were determined: $Ng = 1.686$, $Np = 1.664$, $Ng—Np = 0.022$, $Z \wedge c = 17°$, $(—2V) =$ ca. $80°$.

The plagioclase is andesine or labradorite (An_{30} to An_{60}). Twinning on the albite and pericline laws is common.

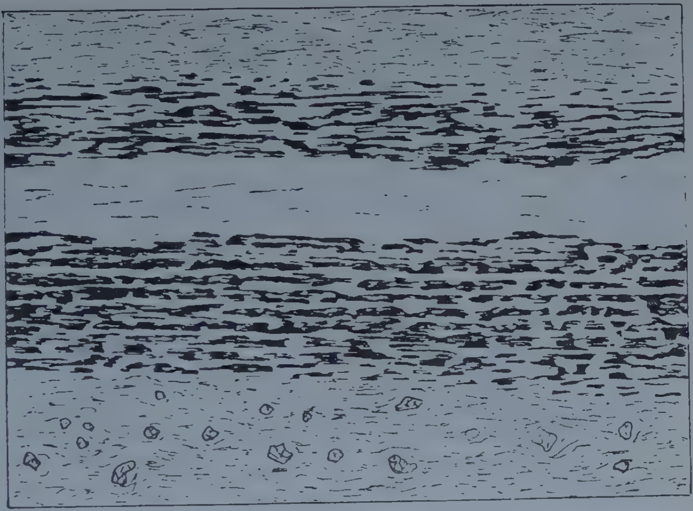

Fig. 14. Alternation between layers of diopside gneiss (white), hornblende gneiss (dark) and garnet-bearing biotite schist (grey). Natural size. From road-cut, Årfor, 9 km west of Foldereid.

Other minerals which occur in varying quantities (they may also be absent), are brown biotite, garnet (almandite) and quartz. Accessory minerals are titanite, zircon, apatite, pyrite and magnetite.

2. Diopside-bearing gneiss.

Megascopically, the members of this group are greenish-grey, medium-grained rocks. Diopside and plagioclase are the chief minerals. In several places, however, hornblende may become an important component of the rock (Fig. 15). Further, these minerals have been found: potash feldspar, biotite, quartz, garnet, tremolite and calcite.

The diopside is greyish green to dark green in specimen. In thin section, it is colorless to pale greenish grey, with no visible pleochroism. The diopside is biaxial positive with $Ng = 1.712—1.730$, $Np = 1.685—1.707$, $Ng—Np = 0.027—0.023$, $Z \wedge c = 42°—44°$, $(+2V) =$ ca. 60°, corresponding to a diopside with an approximate composition ranging from $Di_{72}He_{28}$ to $Di_{44}He_{56}$.

The plagioclase is andesine or labradorite (An_{30} to An_{70}). It is always twinned, primarily after the albite and pericline laws. Zoning may occur.

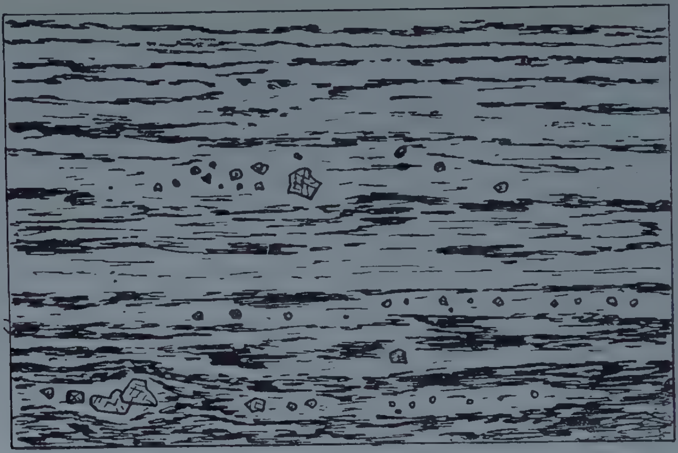

Fig. 15. Lime silicate gneiss with alternating thin layers rich in diopside and garnet (light) and hornblende (dark). Natural size. From Tepling, ESE of Foldereid

The hornblende is usually greenish black in specimen. Under the microscope, it is distinctly pleochroic, with X yellowish green, Y green to brownish green, Z brownish green to dark green. The mineral is biaxial negative with Ng = 1.682—1.685, Np = 1.663—1.665, Ng—Np = 0.019—0.020, $Z \wedge c$ = 17°—20°, 2V is large about X.

The potash feldspar, which is microcline, usually forms small irregular grains in the interstices between the other constituent minerals.

The biotite has the pleochroism: X pale yellow, Y = Z reddish brown to dark brown, assuming darker colors around inclusions of zircon.

The quartz may occur as distinct grains showing undulatory extinction, or it may form thin lenses and veins in the rock.

The garnet is not commonly found. In rare cases, garnet may form small, irregular masses measuring up to 10 cm in size. The color of the garnet is deep brownish red. The index of refraction is fairly constant: N = 1.77—1.78, which probably defines a garnet comparatively rich in the grossularite molecule.

The tremolite, when occasionally present, occurs in colorless long-prismatic crystals.

The calcite always occurs in insignificant amounts, or it may not be found at all.

Other minerals sometimes observed are: scapolite, epidote and clinozoisite. The scapolite is a mizzonite with 60—70 per cent of the meionite molecule.

Accessory minerals are titanite, zircon, apatite, pyrite, pyrrhotite and magnetite. In addition, tourmaline has been noted a few times.

Crystalline Limestone and Dolomite

Crystalline limestone is widely distributed within the Bindal syncline. The thickness of the strata ranges from some few decimeters up to 50 meters or more. The greatest apparent thicknesses seem to exist between Kongsmoen and Tepling, on the north side of the inner part of Indre Folden fjord.

The crystalline limestone is a medium-grained rock. The color is mostly greyish white. Besides calcite, the following minerals have been found: diopside, hornblende (rare), tremolite, phlogopite, biotite, plagioclase (An_{25} to An_{50}), microcline, quartz, epidote and scapolite (Ma_{40-25} Me_{60-75}). Common accessories are: titanite, zircon, apatite, pyrite and pyrrhotite. Less common are tourmaline, graphite and magnetite.

Dolomite-marble has been found in a few places only. The masses are comparatively small in size. The dolomite-marble is a medium-grained rock, pure white in color. In addition to dolomite (the main constituent) have been observed diopside, tremolite, and quartz. In a sample from Steviken, west of Foldereid, which contained white diopside and tremolite (the latter occurring in bundles of colorless needle-like crystals), the following optical properties were determined:
Diopside. $Ng = 1.695$, $Np = 1.666$, $Ng—Np = 0.029$, $Z \wedge c = 40°$
Tremolite. $Ng = 1.630$, $Np = 1.605$, $Ng—Np = 0.025$, $Z \wedge c = 17°$
which, according to the diagrams of WINCHELL (pp. 226 and 246), correspond very closely to pure diopside and tremolite, respectively.

Igneous Rocks

Volcanic Rocks

Apart from a smaller tongue-shaped zone of greenstone and greenschist covering the eastern slope of the Tømmerås Mountain, east of Grong railway station, volcanic rocks have not previously been known

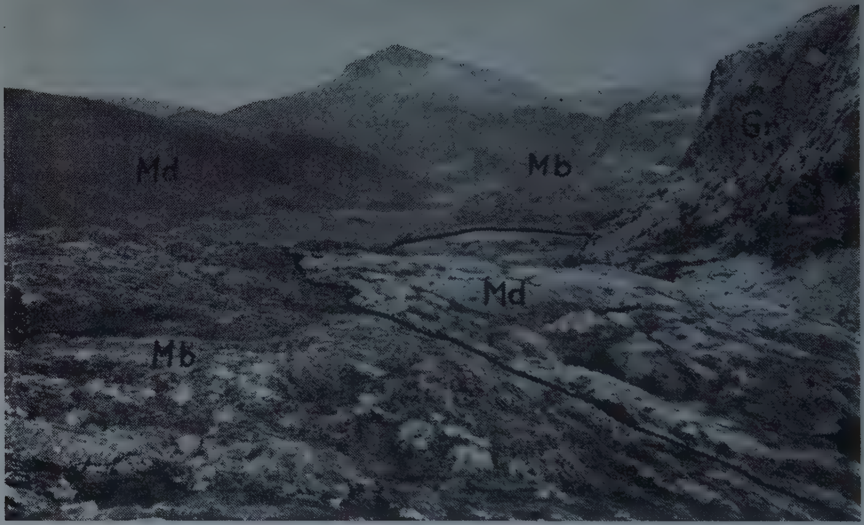

Fig. 16. View of the Kolbotn district looking north. The Kolbotn inlet in the left middle ground and the mountain Heilhornet (1063 m) in the background. Granite (Gr) in the precipice in the upper, right corner. Metadacite (Md) and metabasalt (Mb) in the foreground and to the left.

from the region under consideration (the rocks of the zone just mentioned, representing the southwestern continuation of the extended masses of low-grade metamorphic basic lavas and pyroclastics of the Grong district proper, will not be dealt with in this paper). Now on the east side of the Kolbotn inlet, between Sør fjord and the inner part of Indre Folden fjord, occurs a thick zone of a basic igneous rock which on older geological maps has erroneously been termed gabbro. During the writer's field investigations in the summer of 1946, it was fully ascertained that the said rock actually represents a comparatively slightly altered (uralitized) basaltic lava, a metabasalt after the terminology of some petrologists. Most unexpectedly, however, was the finding of a thin zone of surprisingly well-preserved acid (dacitic) volcanic rocks overlying the metabasalt. The whole complex of lavas is overlain by a large intrusive mass of porphyritic granite.

Subsequent field investigations, carried out by the writer in the summers of 1950, 1951, 1952 and 1955, have proved that metamor-

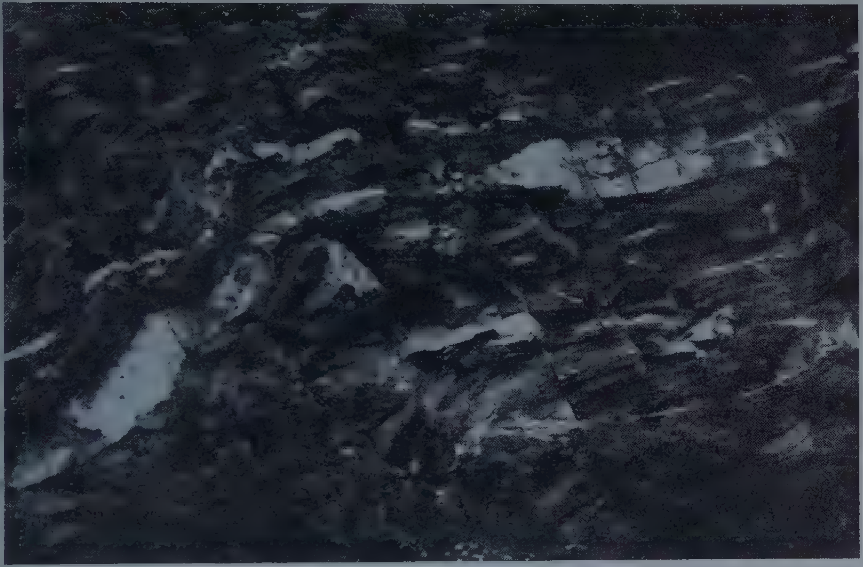

Fig. 17. Sills of trondheimite in metabasalt. From the western precipice of the mountain Strømshatten, on the east side of Kolstrømmen, Kolbotn.

phosed dacitic (rarely andesitic) lavas form the greater part of a zone of volcanic and other supracrustal rocks which can be followed southwards from the Kolbotn district along most of the western boundary of the Bindal granite massif, a distance of about 50 km. From the southern tip of this massif, the zone of altered acid lavas continues in a northeasterly direction towards the Namsen river, where it finally crosses the river at a point about 10 km NNE of Harran church.

In the summer of 1955, during a short stay in the Foldereid district, the writer, again most unexpectedly, found another thick zone of volcanic rocks. The zone, which is situated on the west side of the Kolbotn inlet and below the metabasalt of the same district, consists chiefly of metamorphosed dacitic lavas, occasionally with intervening, thin sheet-like masses of basic lava types. The fact that these lavas, from a point northwest of Foldereid church and northwards for several kilometers, are in immediate contact with the basement complex, presents an interesting stratigraphical problem, which will be discussed elsewhere in this paper.

Besides the various lava types (pyroclastic sediments are rarely

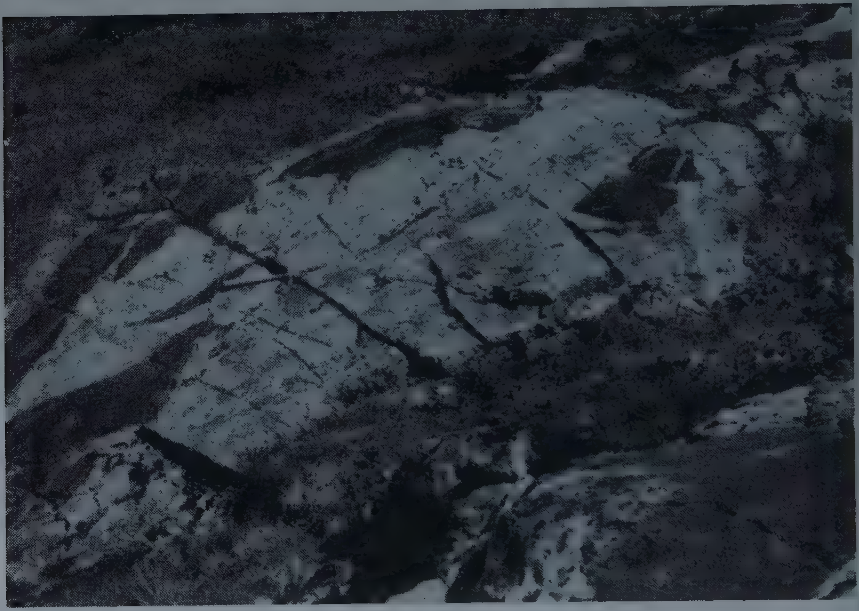

Fig. 18. Sill-like intrusion of trondheimite in metabasalt with inclusions of the latter rock. From the western slope of the mountain of Holandsfjell, east of Foldereid.

met with), beds of quartzite, quartzofeldspathic gneiss, lime silicate gneiss and crystalline limestone may occur. Here and there, this complex of principally volcanic rocks has been intruded by greater or lesser masses of trondheimite, granodiorite and granite (Figs. 17 and 18).

Metabasalt

The metabasalt is dark green in color, and has a weakly to moderately developed parallel structure. The texture may be blastoporphyritic or nonporphyritic.

In the blastoporphyritic type, relatively large prisms of a pale-green amphibole (0.5—1.5 mm in length) are embedded in a groundmass (grain size 0.05—0.2 mm) composed of basic plagioclase and scattered grains of amphibole. The amphibole individuals, which have in many cases retained the crystal outlines of the original pyroxene, are usually haphazardly arranged and may sometimes be aggregated in clusters.

In the nonporphyritic type, the individual grains are practically equi-dimensional, the grains of plagioclase ranging in size from 0.2 to 0.4 mm, those of amphibole and (rare) diopsidic pyroxene from 0.2 to 1.0 mm.

The amphibole is weakly pleochroic, with X colorless to pale yellowish green, Y pale green, Z pale green. In a sample taken from the slope about half-way between Holandsfjell and Kolbænken, northeast of Foldereid, the following optical properties were determined: Ng = 1.660, Np = 1.636, Ng—Np = 0.024, $Z \wedge c = 17°$, which probably correspond to an amphibole with dominating actinolite molecule.

The diopsidic pyroxene, which is colorless in thin section with no visible pleochroism, may be found both as distinct prisms showing more or less alteration to uralite, and as oriented tiny patches in the amphibole. The following optical properties were determined in a specimen collected from the above-mentioned locality: Ng = 1.713, Np = 1.686, Ng—Np = 0.027.

The plagioclase is usually bytownite (Ng = 1.580), but may sometimes have a composition corresponding to acid anorthite (Ng = 1.584). Multiple twinning on the albite and pericline laws is common.

In both rock types small amounts of serpentine (antigorite) may occur, possibly representing an alteration product after olivine.

Garnet has occasionally been found, but is mostly absent. It forms porphyroblasts (of size up to 1.0 cm) with well-defined crystal boundaries, containing numerous inclusions of amphibole and plagioclase.

Epidote is absent as a rock-forming mineral, but may be found together with diopsidic pyroxene, basic plagioclase, amphibole and garnet in small, lenticular aggregates in the metabasalt.

Accessory mineral is magnetite.

Metadacite

The metadacite exhibits a moderate to strong foliation, partly inherited from a primary flow structure, partly representing a secondary schistosity. Where the latter predominates, the metadacite becomes more gneissic in appearance.

The texture is porphyritic, with megascopically visible phenocrysts of one or more of the minerals: plagioclase, hornblende and biotite (Pl. II, fig. 2). Rarely are phenocrysts of quartz, or blastoporphyritic grains of actinolitic amphibole (uralite) found. The ratio of phenocrysts to groundmass is very variable. In the same specimen may be found phenocrysts (for instance of plagioclase) ranging in size from 0.2 to 5—6 mm, although, as a rule, the lower limit of the phenocrysts may be set to about 0.5 mm, the grains of smaller dimensions therefore belonging to the groundmass. The latter may be extremely fine-grained: grains attaining a size of 0.05 mm or less have been observed. In the groundmass, the constituent minerals usually form a microgranular aggregate of irregular grains.

Common accessory minerals are zircon, apatite and magnetite. The following accessory constituents occur only occasionally: potash feldspar (microcline), titanite and pyrite. Secondary minerals are actinolitic amphibole, epidote or clinozoisite, garnet, chlorite and muscovite.

On the basis of the dark constituents, the metadacite may be divided into (1) biotite-bearing, (2) hornblende-biotite-bearing, and (3) uralite-hornblende-biotite-bearing rock types.

(1) Biotite-bearing type. Plagioclase, quartz and biotite are the chief constituents.

The quartz is present only as a groundmass mineral. It shows undulatory extinction.

The plagioclase occurs both as phenocrysts (which are tabular in form) and in the groundmass. Polysynthetic twinning on the albite law is common. Very often this is associated with pericline twinning. The composition of the plagioclase varies from An_{25-30} to An_{40} (basic oligoclase to intermediate andesine).

The biotite is primarily a mineral of the groundmass. It is strongly pleochroic, and reddish brown to dark brown in color. Inclusions of zircon are surrounded by the usual pleochroic halos.

Potash feldspar (microcline), when occasionally present, forms minute, interstitial grains in the groundmass.

Other minerals (of a secondary origin) are epidote or clinozoisite, muscovite (sericite) and garnet. The garnet occurs in badly terminated crystals.

(2) Hornblende-biotite-bearing type. The essential minerals are plagioclase, hornblende, biotite and quartz. The plagioclase and hornblende occur both as phenocrysts and in the groundmass, the biotite

occasionally forms phenocrysts, while the quartz is principally a mineral of the groundmass.

The quartz may show strong undulatory extinction.

The plagioclase is oligoclase or andesine (An_{25} to An_{40}). Phenocrysts exhibiting zonal growth have been observed. Twinning on the albite law, associated with pericline twins, is common. The plagioclase may be somewhat sericitized, while it is usually free of saussuritization.

The hornblende is greenish black in specimen. Under the microscope, it is distinctly pleochroic, with X pale green, Y green, Z bluish green. The hornblende phenocrysts may show simple twinning.

The biotite is brown by transmitted light, and strongly pleochroic. Inclusions of zircon with pleochroic halos are common.

Secondary minerals are epidote or clinozoisite (both sometimes with cores of orthite-epidote), chlorite and muscovite (sericite).

(3) Uralite-hornblende-biotite-bearing type. Phenocrysts of the following minerals occur: plagioclase, quartz, hornblende and biotite, besides which are found smaller, blastoporphyritic grains of actinolitic amphibole (uralite). In the groundmass these minerals occur: quartz, plagioclase, biotite, actinolitic amphibole and potash feldspar.

The quartz often shows strong undulatory extinction.

The plagioclase is andesine (An_{30-40}). Megascopically, the plagioclase phenocrysts can be seen to be greyish-white, glassy, tabular individuals, set in a matrix of fine grain. Under the microscope, they frequently show rectangular cross sections. Twinning is as in the preceding types. Some of the phenocrysts may contain small, optically oriented insets of potash feldspar, the latter mineral being now and then also found as a thin mantle around the larger grains of plagioclase.

The hornblende has the pleochroism: X yellowish green, Y brownish green, Z bluish green. In a sample collected from the western slope of the mountain of Holandsfjell, east of Foldereid, the hornblende was found to have $Ng = 1.675$. The phenocrysts are usually surrounded by a rim of actinolitic amphibole. Otherwise, the two minerals may have grown together in such a way that hornblende forms cores in grains of actinolitic amphibole.

The actinolitic amphibole is doubtless a uralite, but no traces of the original pyroxene have been found. The amphibole is weakly pleochroic in pale-green tones.

The biotite is principally a mineral of the groundmass, but may also be found as phenocrysts (up to 1 mm across). It is brown in color, and strongly pleochroic.

The potash feldspar, which is microcline, occurs in small amounts.

Secondary minerals are actinolitic amphibole and epidote, the latter often with cores of orthite-epidote.

Meta-andesite

Rocks of this kind are rarely met with. A sample was collected on the west side of a little bog between Tepling farm and Tepling summer outfarm, east of Foldereid. In color, the rock is somewhat darker than the metadacite on account of abundant greenish-black hornblende. The texture is porphyritic, with phenocrysts of plagioclase, hornblende and biotite (up to 2 mm in length) set in a groundmass of the same minerals (grain size varying between 0.02 and 0.1 mm). The rock is distinctly foliated.

Quartz is present only in very small amounts. It shows strong undulatory extinction.

The plagioclase is basic andesine (An_{45}). Twinning on the albite law, usually associated with pericline twinning, is common. The feldspar phenocrysts are tabular in form, and may show rectangular outlines. In the groundmass, the plagioclase individuals are often lath-shaped.

The hornblende has the following optical properties: $Ng = 1.680$, $Np = 1.664$, $Ng—Np = 0.016$, $Z \wedge c = 18°$. The pleochroism is distinct, with X pale yellowish green, Y brownish green, Z green.

The biotite is brown to reddish brown in color, and strongly pleochroic. Inclusions of zircon with intense pleochroic halos occur.

Secondary epidote (with cores of orthite-epidote) forms small grains.

Accessory minerals, besides quartz, are titanite, zircon, apatite, magnetite and pyrite.

Tuff

So far, pyroclastic sediments have not been found outside a small area in the zone of altered dacitic lavas on the western slope of the mountain of Skarlandsfjell, in the district of Høylandet. Only tuffaceous rocks occur. They are grey to dark grey in color, fine-grained, and usually stratified. The microscope shows numerous, relatively large plagioclase fragments and scattered flakes of brown biotite, which are embedded in a very fine-grained matrix (grain size about 0.01 mm or less) composed chiefly of quartz and biotite. The plagioclase (oligoclase or andesine) often takes the form of laths. Twinning is common. Some few feldspar grains may also exhibit zonal growth. Other minerals, found in small or accessory quantities, are muscovite, garnet, zoisite, epidote, tourmaline, zircon, apatite and magnetite.

Intrusive Rocks

Serpentine

Altogether 6 small masses of serpentine have been found within the Bindal syncline. 5 bodies occur on the isthmus between the Kolbotn inlet and Indre Folden fjord. Of these, two small bodies (10—15 m in length) appear along the seashore between Bleksviken and Foldereid, here penetrating the Cambro-Ordovician metasediments at points very near the contact with the basement complex. The three other bodies occur in the zone of metabasalt northeast of Foldereid. Two of them are each about 100 m, the third about 250 m in length. The sixth body of serpentine, which has a length of about 10 m, was found in the zone of metadacite north of the mountain of Aurstadfjell, in the Harran district.

A sample taken from one of the above-mentioned three bodies occurring in the zone of metabasalt, had the following mineral composition: olivine, antigorite (secondary after olivine), actinolite and magnetite. The actinolite, which is very poor in iron, might possibly be interpreted as an alteration product of pyroxene.

Saxonite

A small body (about 10 m in length) of a rock of this kind was found in the zone of metadacite just west of the mountain of Holandsfjell, in the Foldereid district. It is a dark-green, medium-grained rock, composed essentially of olivine and hypersthene, and their alteration product, antigorite.

The olivine, which may be strongly serpentinized, occurs in ill-defined crystals measuring from 2 to 5 mm across. The following optical properties were determined: Ng = 1.692, Np = 1.655, Ng—Np = 0.037. According to the diagram of WINCHELL (p. 191), these figures correspond to an olivine with about 10 per cent of the fayalite molecule.

The hypersthene appears in haphazardly oriented, relatively broad prismatic crystals, which may attain a length of up to 2 mm. Under the microscope, the mineral is pale reddish with no visible pleochroism. It has a large optic angle, with Ng = 1.686, Np = 1.676, Ng—Np = 0.010. In the diagram of WINCHELL (p. 218), these data correspond to a hypersthene with about 16 per cent of Fe-silicate. The hypersthene is generally quite fresh, but some individual grains may have been more or less altered to bastite.

Antigorite occurs, as already mentioned, as a secondary mineral after olivine and hypersthene.

Other minerals present are spinel and magnetite. The spinel is dark yellowish brown in thin section, and is therefore probably picotite. It occurs partly in extremely small, rounded grains.

Gabbro

Small, isolated bodies of gabbro have been found in various places within the Bindal syncline. In addition, a large mass of the same rock occurs east of the Namsen river, here making up the high mountain Heimdalshaugene, at the southeastern corner of the map, Fig. 11.

The gabbro is dark-colored, medium-grained, and usually massive. Sometimes, however, it may be strongly foliated, and should then be termed amphibolite. Plagioclase and green amphibole are the main constituents.

The plagioclase may be more or less saussuritized and sericitized. The composition varies from intermediate andesine to acid oligoclase.

The amphibole has the pleochroism: X yellowish green to almost colorless, Z bluish green to pale green. According to its optical character, there can be no doubt as to the secondary development of this mineral, which has been formed at the expense of the primary pyroxene.

Other minerals which occur in subordinate or accessory amounts are chlorite, epidote, clinozoisite, sericite, biotite, quartz, titanite, apatite, rutile, pyrite and magnetite.

Acid Intrusives outside the Bindal Granite Massif

Quartz-diorite

A zone of quartz-diorite occurs northeast of Gartland, in the Harran district. The zone, which runs approximately parallel to the Namsen river, has a length of about 30 km and a width of 2 to 4 km. In the main rock may be found smaller, usually concordant, narrow bodies of gabbro, amphibolite, trondheimite and granodiorite. The quartz-diorite is a dark-grey, medium-grained, distinctly foliated rock, with quartz, plagioclase, hornblende and biotite as the principal constituents.

The quartz shows strong undulatory extinction. The plagioclase is oligoclase or andesine (An_{25} to An_{37}). The hornblende is of the common green type. The biotite is brown, and strongly pleochroic. Minor constituents are muscovite, epidote (or clinozoisite), titanite, orthite-epidote, zircon, apatite and pyrite.

Trondheimite

A larger massif of this rock occurs in the area southeast of the Namsen river. Trondheimite may also be found as veins, sills and other narrow intrusions in the above-mentioned zone of quartz-diorite, as well as in the complex of metasediments and metavolcanics. The trondheimite is light grey, medium-grained, and often distinctly foliated. These minerals have been observed: quartz, plagioclase, biotite, muscovite, epidote, titanite, orthite-epidote, zircon, apatite and pyrite.

The quartz exhibits strong undulatory extinction. The plagioclase is basic oligoclase. Scattered plagioclase crystals may attain a size of up to 6 mm, giving the rock a faintly porphyritic texture. The biotite is brown, and strongly pleochroic. The muscovite occurs in small flakes, while the epidote forms small, irregular grains, which may have cores of orthite-epidote.

Trondheimite Porphyrite

This rock occurs as veins and sills in the supracrustal complex. Megascopically, it is a light-grey, medium- to fine-grained rock. The microscope shows a porphyritic texture with phenocrysts of plagioclase and sometimes phenocrysts of quartz and biotite in a groundmass of the same minerals.

The plagioclase is acid andesine. Potash feldspar (microcline) is present only in subordinate amounts. The biotite is strongly pleochroic, and reddish brown to dark brown in color. Muscovite forms relatively large, scattered flakes in some thin sections. Common accessory minerals are zircon and apatite. Occasionally, tourmaline, orthite-epidote and magnetite may be found in addition.

Granodiorite

This rock forms narrow dikes and sills in the supracrustal complex. It is a grey to light-grey, medium- to finer-grained rock. The chief minerals are quartz, plagioclase and potash feldspar.

The plagioclase is oligoclase (An_{20} to An_{30}). The potash feldspar is microcline or microcline microperthite. Biotite is the principal dark constituent. In rare cases, a colorless diopsidic pyroxene may be found. Accessory minerals are titanite, zircon, apatite and magnetite.

A sample taken from a dike (10—15 cm thick) in a road-cut near Sjølstad, 5 km west of Foldereid church, shows abundant black tourmaline and a little garnet. The tourmaline, which occurs in up to 3 cm long prismatic crystals, has the following optical properties: No = 1.662, Ne = 1.638, No-Ne = 0.024. It shows the pleochroism: X pale reddish, Z bluish green. The tourmaline is probably an iron-rich member of the schorlite-dravite series. The garnet forms small, homogeneous crystals which may be up to 1 mm across.

Granodiorite Porphyry

Two rock types can be distinguished: one type with biotite, and the other with hornblende as essential dark constituents.

1. Biotite-bearing type. This rock has been found as narrow sills in the metasediments and metavolcanics of the Foldereid-Kolbotn district. It is grey to light grey and porphyritic, with phenocrysts of plagioclase and quartz, and sometimes phenocrysts of potash feldspar and biotite in a fine-grained groundmass made up of quartz, plagioclase, potash feldspar and biotite.

The quartz forms phenocrysts which may be up to 3 and 4 mm in diameter.

The plagioclase is basic oligoclase. The phenocrysts may attain a length of 6 mm or more. Myrmecite occurs in small amounts.

The potash feldspar is microcline or microcline microperthite. The phenocrysts, when present, may attain a maximum length of about 1 cm.

The biotite is present in varying amounts. It is reddish brown to dark brown, and strongly pleochroic.

Minor constituents are titanite, orthite-epidote, zircon, apatite and magnetite.

2. Hornblende-bearing type. This rock occurs as a thick sill-like mass penetrating the zone of altered lavas on the western slope of the mountain of Holandsfjell, in the Foldereid district. It is a darker-grey, medium-grained rock. Quartz, plagioclase, potash feldspar, hornblende and biotite are the main constituents, all of which occur in two generations.

The plagioclase is basic oligoclase (An_{28}). The phenocrysts (up to 3 mm in size) may contain small insets of potash feldspar.

The potash feldspar is microcline. Along the edges of the large and medium-sized microcline phenocrysts (up to 1 cm in length) may be found numerous grains of a coarse myrmecite.

The hornblende is of the common green type.

The biotite is brown, and strongly pleochroic.

Diopsidic pyroxene and epidote occur in small amounts, the former being found as cores in the hornblende.

Accessories are titanite, orthite-epidote, zircon, apatite and magnetite.

Granite

Granite has been found a few times as narrow intrusive bodies in the supracrustal complex. It is a light-grey, medium-grained rock with quartz, microcline and acid oligoclase as the principal constituents. Biotite and muscovite occur in small amounts. Accessory minerals are titanite, zircon, apatite, pyrite and magnetite.

The Bindal Granite Massif

This massif is a composite intrusion consisting (within the present area) of (1) an outer, not too well-defined zone of medium-grained granitic rocks, and (2) a more central, large body of coarse-grained, porphyritic granite. The outer zone varies considerably in width, from zero to several kilometers. It is thus completely lacking along a greater part of the southwestern boundary of the massif, from a point opposite Lake Øie vatn to Sør fjord, where, in its stead, the body of porphyritic granite is in immediate contact with the underlying complex of metasediments and metavolcanics.

(1) In the outer zone of the Bindal massif granodioritic types predominate. True granites have been found only locally. A characteristic structural feature of these intrusives is the occurrence of numerous, small flake-like masses of country rock, all of which are concordant with the foliation of the enclosing pluton. Outside the massif, in a belt of varying breadth, the adjacent country rocks have been injected by innumerable bodies (veins, sills, etc.), varying in thickness, of principally granodioritic composition. Typical migmatites are especially common on the south and southeast side of the massif.

The granodiorites and granites of the outer zone are light-colored, medium- to fine-grained rocks, which may be strongly foliated. Sometimes a typical mortar texture has been developed. The chief constituents are quartz, potash feldspar, acid plagioclase and biotite.

The quartz often shows strong undulatory extinction.

The potash feldspar is usually microcline, less frequently microcline microperthite.

The plagioclase is intermediate oligoclase. It may contain tiny insets of potash feldspar. Myrmecite is present in small amounts.

The biotite, which occurs as small, ragged individuals, is brown to reddish brown, and strongly pleochroic.

Other minerals, mostly occurring in subordinate quantities, are muscovite, chlorite (secondary after biotite) and epidote.

Accessories are titanite, orthite-epidote, zircon, apatite and magnetite.

(2) The intrusive rock which makes up this part of the Bindal massif is a grey to light-grey granite of coarse to very coarse grain. It is porphyritic with tabular crystals of feldspar, chiefly potash feldspar (of size up to 5.0 by 2.5 by 1.5 cm), in a finer groundmass composed of quartz, potash feldspar, acid plagioclase and biotite. Less important constituents are hornblende and diopsidic pyroxene. Occasionally, the granite may be crushed and mylonitized.

The quartz may show strong undulatory extinction.

The potash feldspar is partly microcline, partly microcline microperthite. The larger individuals of this mineral often contain small grains of acid plagioclase, and, conversely, the potash feldspar may be found as patches and rectangular insets in the plagioclase.

The plagioclase is intermediate oligoclase. Myrmecite occurs in small quantities.

The biotite is brown, and strongly pleochroic.

The hornblende has the pleochroism: X yellowish green, Y green, Z bluish green. The optic angle is moderate, with $2V = 50°—60°$ about X.

The diopsidic pyroxene is weakly pleochroic, and greyish green to yellowish green in color.

Epidote is present only in insignificant amounts.

Accessories are titanite, zircon, apatite and magnetite.

NOTE ON THE MINERAL FACIES

The bulk of the sedimentary and volcanic rocks of the Bindal syncline were no doubt metamorphosed under physical conditions that correspond to the requirements of the staurolite-cyanite subfacies of the amphibolite facies (TURNER and VERHOOGEN, op. cit.). It is, further, highly probable that there exists a close connection between the metamorphic development of the supracrustals, and the emplacement of the plutonic series of granite and granodiorite. The main result of the introduction of large quantities of granitic magmas into the geosyncline seems to have been a regional increase of metamorphic temperature which, together with strong orogenic movements, gave the whole rock system its final petrographical character.

The mineralogy of the different types of metasediments which occur within the Bindal syncline will be apparent from the following assemblages:

1. Quartzite and quartz schist.
   a. Quartz-oligoclase-biotite-muscovite.
2. Quartzofeldspathic gneiss.
   a. Quartz-oligoclase-microcline-biotite-muscovite.
   b. Quartz-oligoclase-biotite-muscovite-almandite (-epidote).

3. Micaceous gneiss.
    a. Quartz-oligoclase-biotite-muscovite-almandite (-epidote).
4. Mica schist.
    a. Quartz-biotite-muscovite.
    b. Quartz-biotite-muscovite-plagioclase-almandite.
    c. Quartz-biotite-plagioclase-almandite.
    d. Quartz-biotite-plagioclase-almandite-cyanite.
    e. Quartz-biotite-muscovite-plagioclase-almandite-staurolite-cyanite.
    f. Quartz-biotite-muscovite-plagioclase-staurolite-cyanite.
    g. Quartz-biotite-plagioclase-staurolite-cyanite-hornblende.
    h. Quartz-biotite-plagioclase-epidote-calcite.
    i. Quartz-biotite-plagioclase-hornblende-epidote-calcite.
    j. Quartz-biotite-plagioclase-diopside-zoisite-calcite.
5. Lime silicate gneiss and related amphibolitic rocks.
    a. Hornblende-plagioclase (-biotite-almandite-quartz).
    b. Hornblende-diopside-plagioclase-biotite.
    c. Diopside-hornblende-plagioclase-microcline-calcite.
    d. Diopside-tremolite-plagioclase-microcline-biotite.
    e. Diopside-plagioclase-microcline-biotite-quartz.
    f. Diopside-hornblende-plagioclase-microcline-garnet (grossularite-bearing)-epidote.
    g. Diopside-garnet (grossularite-bearing)-plagioclase (-scapolite-epidote-microcline).
6. Crystalline limestone and dolomite.
    a. Calcite-diopside-plagioclase-microcline-quartz.
    b. Dolomite-diopside-tremolite.
    c. Dolomite-tremolite.

From the above list it will be seen that the maximum number of minerals assumed to be in equilibrium is in most of the epidote-free assemblages five, while in rocks containing epidote (alternatively clinozoisite or zoisite) as an additional phase it may be raised from five to six. The appearance of biotite as a sixth constituent of rocks conforming to the assemblages 4 f and g may possibly be explained by the strictly limited capacity of Mg to replace Fe in staurolite.

The paragenesis hornblende-cyanite-staurolite is not commonly found within the region under consideration.

Equally rare is the assemblage 4 e. Containing altogether seven mineral phases, including each of the minerals staurolite, cyanite and almandite, the said association can hardly be considered as being in equilibrium. Stable parageneses are, for instance, staurolite-cyanite and cyanite-almandite. They are connected through the following equation (TURNER and VERHOOGEN, op. cit., p. 454. See also TH. VOGT, 1927, pp. 437—438):

$$\underset{\text{Staurolite}}{3FeAl_4Si_2O_{10}(OH)_2} + \underset{\text{Quartz}}{2SiO_2} \rightleftarrows \underset{\text{Almandite}}{Fe_3AL_2(SiO_4)_3} + \underset{\text{Cyanite}}{5Al_2SiO_5} + \underset{\text{Water}}{3H_2O}$$

On increase of temperature, the state of equilibrium will be shifted towards the right. A possible explanation of the assemblage 4 e is, therefore, that the process whereby cyanite and almandite originated at the expense of staurolite and quartz has, in some way or other, been sufficiently retarded as to impede a complete reaction from left to right.

In this connection might be mentioned the fairly common appearance of muscovite in the calcite-bearing mica schists which occur in the southernmost part of the syncline (assemblage 4 h). The paragenesis muscovite-calcite may indicate that chemical equilibrium was not always attained during the development of the said rocks. Another explanation would be that the muscovite was formed through retrogressive metamorphism. At any rate, there is here, in the district south of the Bindal massif, a decided fall in the metamophic grade of the altered (chiefly pelitic) sediments from the north towards the south and southeast.

Besides certain types of mica schist and gneiss, the microcline-bearing lime silicate gneisses and associated marbles represent the highest stage of metamorphism attained by any rock of sedimentary origin within the Bindal syncline. It is evident that in rocks of this kind with an excess of quartz, hornblende, at the prevailing metamorphic temperature, has been chemically unstable in contact with calcite, the stable mineral being diopsidic pyroxene (assemblage 5 e). Above a certain lower limit of temperature, hornblende will react with calcite and quartz according to the equation:

$$\underset{\text{Hornblende}}{Ca_2(Mg, Fe)_5(Si, Al)_8O_{22}(OH)_2} + \underset{\text{Calcite}}{3CaCO_3} + \underset{\text{Quartz}}{2SiO_2}$$
$$\rightleftarrows \underset{\text{Diopsidic pyroxene}}{5Ca(Mg, Fe)(Si, Al)_2O_6} + \underset{\text{Gas}}{3CO_2 + H_2O}$$

The said reaction has not always proceeded to completion. This is indicated by the finding of small, pleochroic patches of hornblende in the larger grains of diopside. Again, in rocks characterized by deficiency of quartz, the two minerals may occur alongside in a stable combination, as exemplified by the assemblages 5 b, c and f.

In this mineral facies, potash feldspar should, hypothetically, be unstable in the presence of one or more of the minerals staurolite, cyanite and almandite, and, in fact, such parageneses have never been observed in the mica schists of the Bindal syncline. Nevertheless, the association garnet-potash feldspar is not uncommon in certain types of lime silicate rocks which occur in the district between Kongsmoen and Foldereid, on the north side of the inner part of Indre Folden fjord. In this case, however, it can be proved that the garnet is not almandite, but a grossularite-bearing member of the garnet group (assemblages 5 f and g).

Another feature worth mentioning is the fact that tremolite, in calcareous rocks of appropriate composition, has been stable up to the highest metamorphic temperatures known for the area (assemblage 5 d). Further, there is reason to believe that the upper limit of the field of stability of epidote has sometimes been passed. This may possibly be due to the combined effect of high temperature and relatively high confining pressure. Where, however, the rocks have been subjected to strong compressive stress during a shorter or longer period of deformation, accompanied by decrease of temperature, an epidote mineral appears. The igneous rocks show many examples of this approach to the new physical conditions characterized by high stress and relatively low temperature.

STRATIGRAPHY AND TECTONICS

The geological structure of the Bindal syncline gives evidence of intense orogenic movements, and extensive, plutonic igneous activity. The tectonic picture is that of a strongly compressed syncline, the axis of which dips gently towards the northeast. Southwards, the syncline goes into the air, being, therefore, detached from the Snåsa syncline by an east-west oriented "barrier" of the basement complex.

The formation of the geosynclinal belt was probably initiated in the Cambrian and continued in the Lower Ordovician, with the simultaneous deposition of thick strata of pelitic sediments, including clayey and marly types. Basal conglomerates are unknown from the Bindal syncline.

The series begins with a mica schist representing a metamorphosed argillaceous sediment poor in lime. The mica schist, which can be followed along a considerable part of the western boundary of the syncline, probably nowhere exceeds 200 m in thickness. Usually the zone is much thinner. Higher up in the series, a mica schist with abundant calcite and lime silicates becomes the predominant rock type. In addition, thin layers of crystalline limestone and dolomite-marble may occur here and there. These changes of facies also take place laterally, the mica schist in the area north of Lake Øie vatn gradually giving way to more calcareous rocks. The latter are different types of lime silicate gneiss and associated marbles, which form large masses in the district around the inner part of Indre Folden fjord.

The said group of metamorphosed sedimentary rocks is succeeded by a thick series of comparatively slightly altered basaltic and dacitic (rarely andesitic) lavas. They have been termed metabasalt, metadacite and meta-andesite by the present writer. In the acid (-intermediate) lavas, beds of dacitic tuff and layers, varying in thickness, of various types of metasediments may occur locally.

In the Kolbotn district, north of Foldereid, altogether three individual horizons of volcanic rocks can be distinguished. Dipping gently eastwards, these are, from bottom to top (Fig. 16):

1. Lower zone: Mainly altered dacitic lavas. Thickness, 800 m.
2. Middle zone: Uralitized basalt. Thickness, 1100 m.
3. Upper zone: Altered dacite. Thickness, 75 m.

As will appear from the map, Fig. 11, the lower volcanic zone of the Kolbotn district is in immediate contact with the basement complex, from a point about 2 km northwest of Foldereid church, to Sør fjord. This fact may be explained in two ways:

a) The contact is an unconformity.
b) The contact is a thrust plane along which younger rocks have been thrust over older ones.

Now, field observations on the western flank of the syncline prove the existence of a fault nearly 50 km long, extending southwards from Årsandøy (at the entrance to the Kolbotn inlet) to a point just east of Lake Øie vatn. The fault, approximately following and in many places coinciding with the western boundary line of the Bindal granite massif, dips relatively steeply east towards the deeper parts of the syncline. Actually, this fault is a fault zone, several meters thick, constituting a system of closely spaced slip planes along which the rocks have been intensely crushed. Minor faults may or may not occur a little farther west, but what is important in this connection is the fact that corresponding faults associated with brecciation and mylonitization phenomena have never been observed along the contact between the Cambro-Ordovician supracrustal rocks and the basement complex. As to the origin of the said major fault, there are two possible explanations. The fault may represent an upthrust, whereby the eastern block might be imagined to have moved up relative to an essentially stationary western rock complex. Another explanation would be that the faulting took place after the main phase of folding, in a period of increasing tensional stresses. In this case, where the eastern block is assumed to have moved down, whilst the western block remained stationary, the term normal or gravity fault might be used. In the opinion of the present writer, the former explanation accords best with the observed data.

To sum up, there is nothing to show that thrust movements have taken place along the western boundary of the Bindal syncline. Consequently, the metamorphosed Cambro-Ordovician rocks west of the major fault must be considered autochthonous or at least parautochthonous. The problem concerning the lower volcanic zone of the Kolbotn district is thereby reduced to a purely stratigraphical one. In addition, an unconformity might also be suspected to exist between the acid volcanic rocks farther south, and the underlying Cambro-Ordovician metasediments. However, field observations indicate that there is actually a passage between the two rock series.

The metabasalt of the Kolbotn district is probably unrelated to the low-grade basic volcanic rocks (greenstone, greenschist) found, for example, in the Grong district and in the Trondheim region, including the Snåsa syncline. Rocks of the latter kind, representing basic lavas and tuffs which were erupted in great volumes during the Skiddavian epoch, have been found in widely separated areas of the Caledonian orogenic zone of northwestern Europe. Slightly younger than these rocks, but belonging to the same phase of volcanic activity,

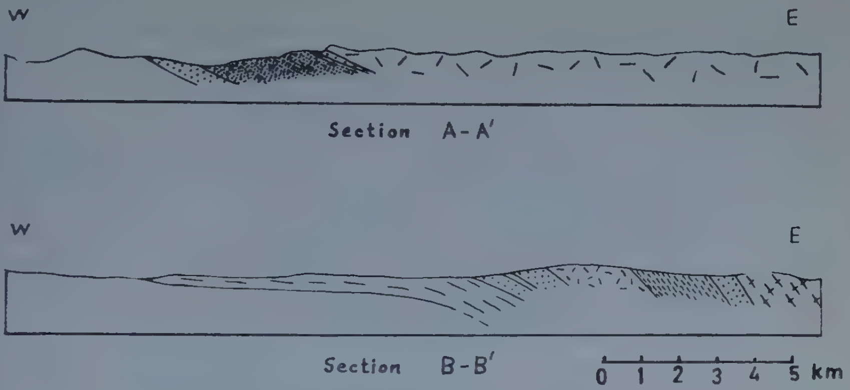

Fig. 19. Cross sections of the southwestern part of the Bindal syncline along the lines A—A' and B—B' of Fig. 11. Symbols the same as for Fig. 11.

are probably the altered basaltic and associated dacitic (rarely andesitic) lavas which occur within the Bindal syncline. From the Hølonda—Horg district in the Trondheim region, Vogt (1945) has described rock types which may represent altered andesitic lavas. They are assumed to be of Llandeilian age. Volcanic rocks of a similar age, comprising lavas, tuffs and agglomerates, also occur in various parts of Great Britain, e. g., in the south of Scotland and in northern England. In both regions the lavas are mainly andesites.

The volcanic rocks of the Bindal syncline are overlain by a series of metasediments, including such types as quartzite, mica schist, gneiss and crystalline limestone. This series constitutes the upper part of a thick succession of supracrustal rocks which were deposited in Cambro-Ordovician time under geosynclinal conditions.

During the main phase of the Caledonian orogeny, the geosyncline was strongly compressed, simultaneously as the eastern limb of the Bindal syncline was inverted towards the west (Fig. 19). The folding movements were accompanied by intense intrusive activity, through which magmas of granitic and granodioritic composition protruded in large quantities near the central basal part of the syncline. The Bindal massif is no doubt the result of several successive intrusions of this kind. The form of the massif is that of a phacolith which dips towards the east. The dip is low to moderate in the northwest and west, while it is moderate to relatively steep in the east. The lower side of the phacolith runs parallel to, and may sometimes truncate, the zone of volcanic rocks. Consequently, the upper sedimentary series is lacking on the west (or normal) limb of the syncline.

In a recent paper, STRAND (1953) has put forward the suggestion that the geological structure of the Caledonian mountain chain in southern Nordland and adjoining parts of northern Trøndelag may be explained as the result of a large-scale overthrusting (see also CHR. OFTEDAHL, 1956). STRAND distinguishes between two tectonic units: a western complex made up of granitic intrusives and sedimentary rocks of relatively high metamorphic grade, and an eastern complex of less metamorphosed rocks. The former complex, which according to the same writer has the character of a nappe, overlies the eastern one, thus indicating a thrust direction from west to east.

To this view, however, objections may be raised. The principal objection is closely connected with the finding of the above-mentioned zone of metamorphosed basic and acid lavas. The demonstration of this zone as constituting a leading stratigraphical level in the series of supracrustal rocks in the region under consideration, together with the fact that the same zone, in the Kolbotn district, appears to rest on the basement complex with a great unconformity, supports the idea that the rock masses of the Bindal syncline lie essentially *in situ*.

Nevertheless, there can be little doubt that fault movements have taken place within the boundaries of the syncline. These faultings, which indicate comparatively small, steeply inclined displacements (the term upthrust may be used), probably date from a later phase of the Caledonian orogeny, characterized by intense compressive stresses. In the southern part of the syncline, the deformation may be pictured as a compression of rock masses of relatively low competency between two rigid blocks represented by the Bindal massif, in the west, and the large intrusive body of the mountain of Heimdalshaugene, in the east. This would involve a horizontal lengthening of the rock masses in a northeast-southwest direction. There is also evidence of strong differential movements. Thus, near Fiskumfoss, in the Harran district, more competent masses built up chiefly of acid intrusive rocks have been pushed southwards over a weaker zone of mica schist. The thrust, dipping gently to the north, is easily seen in the landscape on both sides of the Namsen river.

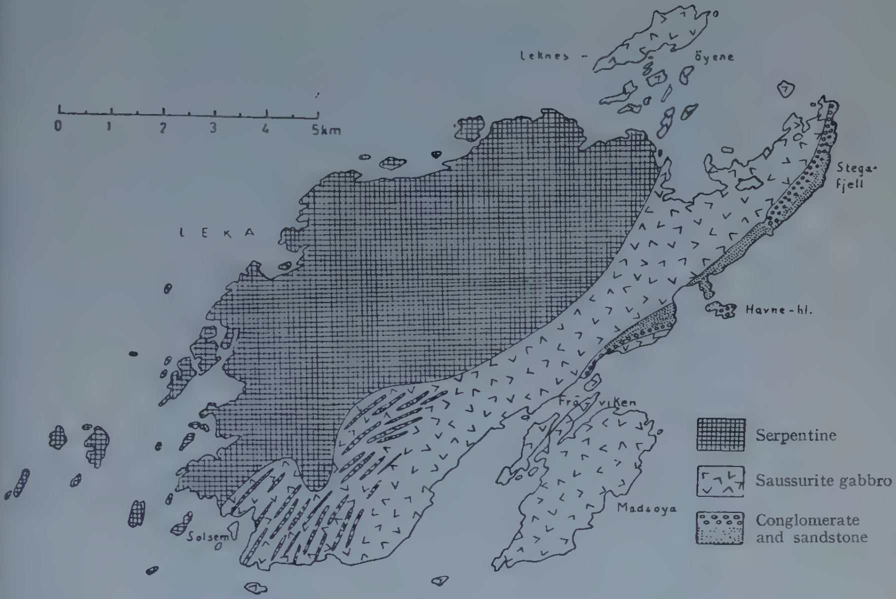

Fig. 20. Geological map of the Leka district.

The Leka District

Leka is a large island situated on the coast just south of the border between the counties of Nordland and northern Trøndelag. Smaller islands belonging to the same geological unit are found especially to the north, southeast and southwest of the principal island.

Most of the Leka district is occupied by an old intrusive complex consisting mainly of basic and ultrabasic rock types. Overlying this complex is a series of younger sediments. The latter, as a result of intense orogenic pressure, has been forced into a narrow syncline, the axial plane of which dips steeply towards the southeast (Fig. 20).

THE OLD COMPLEX

The predominant rocks are serpentine and saussurite gabbro. In the latter, minor intrusions of trondheimite may occasionally be found.

Serpentine

Serpentine makes up about two thirds of the island of Leka, and is also found in the islets farther west. In the southwestern part of

Leka, this rock occurs intimately associated with saussurite gabbro in the form of steeply inclined sheets or narrow lenses.

The serpentine is dark green on fresh fractures, and massive. Sometimes it may show a banded structure.

The following minerals have been observed: antigorite, amphibole, diopsidic pyroxene and ore. The antigorite, which is the chief constituent, occurs as blades 0.01 to 0.1 mm in length. The amphibole forms small colorless prisms and needles. The pyroxene, when present, shows alteration to antigorite. It is colorless in thin section. $Z \wedge c =$ ca. 45°. The ore is probably mostly chromite. Olivine has not been found.

Saussurite Gabbro

Saussurite gabbro forms the greater part of eastern Leka, the whole of Madsøya with neighbouring islets, and the islets of Leknesøyene.

Megascopically, the saussurite gabbro is a medium-grained rock of greyish-green color. It is often rather massive, but may also be strongly foliated.

The rock is always completely saussuritized and uralitized. Amphibole and albite are the chief minerals. Other constituents are chlorite, epidote, zoisite, calcite and quartz. The original plagioclase has been altered into a mixture of albite, zoisite (epidote) and quartz. The albite usually exhibits no twinning. The amphibole has the pleochroism: X colorless, Z yellowish green to green.

Trondheimite

Trondheimite occurs locally as dikes and other small bodies in the saussurite gabbro.

The trondheimite is a greyish-white, medium- to fine-grained rock. It is usually somewhat crushed. This is confirmed by the microscope, which shows a well-developed mortar texture, with larger angular grains of albite and quartz set in a fine-grained matrix of the same minerals. While the larger albite individuals are more or less sericitized, the albite of the matrix is not (probably a recrystallization phenomenon). Chlorite is present in small amounts. Accessory minerals are zircon, apatite and pyrite.

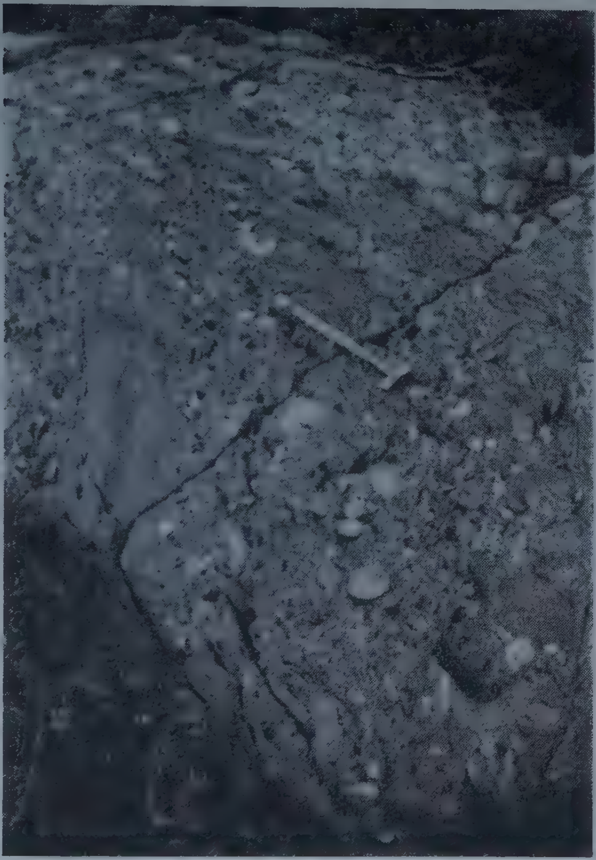

Fig. 21. Conglomerate. From the ridge Stegafjell, Leka.

THE YOUNGER SERIES

The great bulk of this series is made up of conglomerate and sandstone. In addition, thin zones of phyllite and crystalline limestone may occur.

Conglomerate

The conglomerate attains its maximum thickness in the Stegafjell area, northeastern Leka, where it is in contact with the underlying massif of saussurite gabbro. Conglomerate is also found farther south, on the islet of Havneholmen. It reappears on the island of Leka and continues southwestwards as a relatively thin zone which disappears under the sea at a point about 1 km northeast of Frøviken.

The conglomerate is distinctly polygenous, with cobbles and pebbles of different rock types lying more or less densely packed in a comparatively fine-grained matrix of sandstone character (Fig. 21). Sandstone may also occur as thin beds in the conglomerate.

Prominent among the larger fragments are cobbles and pebbles of serpentine. The cobbles may be well rounded, but equally frequently it happens that they are not. This is particularly true of the minor pebbles, which often exhibit angular outlines.

Besides the fragments of serpentine, occur scattered well-worn cobbles of metagabbro and trondheimite, and ill-defined fragments of a rock that has been termed quartz porphyrite by the present writer.

The metagabbro differs somewhat in texture and mineral composition from the saussurite gabbro of the old complex. It is medium-grained and unfoliated. The rock consists essentially of albite and green amphibole. The albite occurs in polysynthetically twinned lath-shaped individuals. The amphibole has the pleochroism: X pale yellowish green, Z bluish green. Biotite and chlorite are present in small amounts.

The trondheimite is a light-colored, medium-grained, massive rock. Albite and quartz are the principal constituents. The albite is often strongly sericitized. Some of the albite individuals may contain numerous, minute grains of epidote. Other minerals which occur are brown biotite, zircon and apatite.

The quartz porphyrite is light grey on fresh fractures, almost white on weathered surface. It is very fine-grained, appearing almost dense in hand specimen. The microscope shows that the rock is porphyritic, with unoriented lath-shaped phenocrysts of albite (up to 1.0 mm in size) in a groundmass of albite and quartz (grain size down to 0.01 mm). A brown biotite is present in small amounts, together with a little chlorite.

Associated with the rocks described above occur individual grains of different minerals: more or less rounded grains of quartz, angular fragments of albite, and flakes of biotite and chlorite. Calcite is also present, as are scattered grains of zircon and apatite. Epidote is mostly absent. Tourmaline is rarely found.

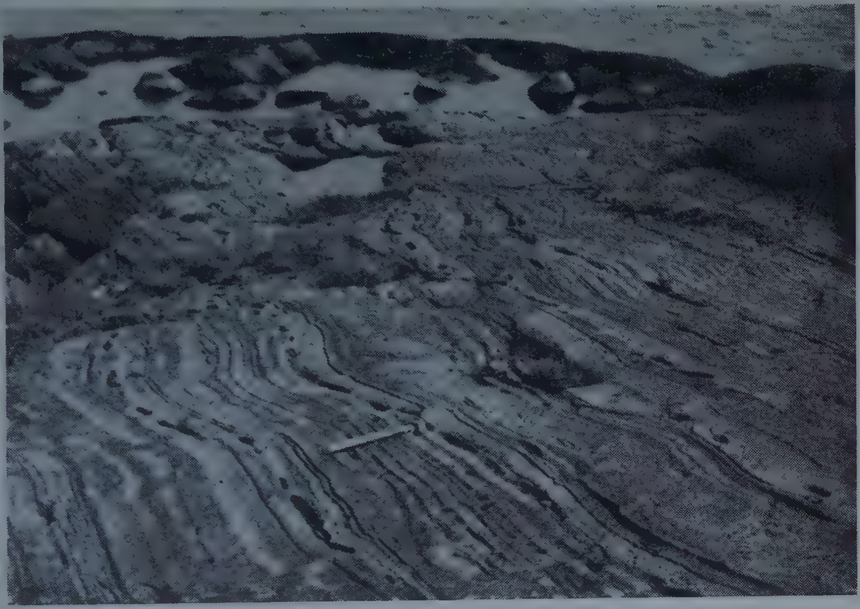

Fig. 22. Bedding in slightly metamorphosed feldspar-bearing sandstone. From the promontory to the south of Skei. Leka.

Sandstone

Megascopically, the sandstone is a fine- to medium-grained rock of grey, greenish-grey, or dark-grey color. Sometimes a well-developed bedding may be found (Fig. 22).

The microscope shows a clastic fabric with larger angular grains of quartz and albite, in a groundmass of quartz, albite, biotite, chlorite and muscovite. In addition, small rock fragments composed of albite and quartz may occur. Outside the groundmass, biotite and chlorite are often found in flakes, up to 2 mm long. Calcite is present in most thin sections, forming grains of varying size.

The quartz shows undulatory extinction.

The albite has the composition An_{3-10}. It is usually twinned according to the albite and pericline laws, less frequently on the Carlsbad law. As the recrystallization proceeds, the twinning disappears. In addition, the recrystallized albite grains are never sericitized.

The biotite is generally somewhat chloritized.

The muscovite is sericitic in habit.

Other minerals which may occur are amphibole (probably actinolitic) and clinozoisite. The amphibole forms narrow, 2—3 mm long prisms. It has the pleochroism X pale yellow, Y pale green, Z green. $Z \wedge c$ = ca. 14°. The clinozoisite occurs in small prisms, attaining a length of 0.5 mm.

Minor constituents are tourmaline (rare), zircon, apatite and pyrite.

Phyllite

This rock appears in the sandstone in a few non-persistent zones, each less than 10 m thick. The color varies from greenish grey to nearly black. Under the microscope are seen small porphyroblasts of brown biotite (up to 1.5 mm in diameter) in a fine-grained groundmass of quartz, muscovite (sericite) and a little biotite. Less commonly are found small idioblastic crystals of garnet (probably a member of the spessartite-almandite series). Feldspar has not been observed with certainty. Other minerals which occur are tourmaline, graphite and pyrrhotite. The tourmaline is found in slender prisms, up to 1 mm long. It has the pleochroism X colorless, Z brownish green.

Crystalline Limestone

Only one zone of crystalline limestone has been found. It is situated in the southwestern, narrow part of the syncline, where it lies between a relatively thick layer of conglomerate and a broader belt of sandstone. The zone, which has a maximum thickness of 7 m, can be traced for about 1.5 km.

The rock is greyish white, with tinges of green and red, is fine-grained, and slightly foliated. It is completely recrystallized. Besides calcite, occur subordinate amounts of clinozoisite, albite, muscovite, quartz, tourmaline, apatite and graphite.

AGE OF THE ROCKS

The Leka district is characterized by the absence of rock series older than the complex of metamorphosed basic and ultrabasic intrusives. The oldest rock within this complex is the saussurite gabbro, as it has been injected not only by the trondheimite but also by the serpentine. In southern Leka, the intrusion of the serpentine into the saussurite gabbro has partly taken place in the form of steeply dipping, dike-like bodies, trending northeast-southwest. The relation of the trondheimite to the serpentine is not quite clear, but probably the trondheimite is the younger rock.

The conglomerate of the younger series consists partly of rock fragments which are undoubtedly derived from the old complex, viz. serpentine, and partly of fragments of an igneous type that is no longer found in solid rock of the substratum, viz. quartz porphyrite. With regard to the other rock types which occur as cobbles and pebbles in the conglomerate, viz. unfoliated metagabbro and massive trondheimite, they may or may not correspond respectively to the saussurite gabbro and the trondheimite of the substratum. In the present paper, this conglomerate is tentatively correlated with the serpentine conglomerate at Otta, in Gudbrandsdalen, which, according to VOGT (1945, p. 507), may perhaps be contemporaneous with the Venna conglomerate at the base of the Lower Hovin series in the Trondheim region. Now, the age of the Otta conglomerate has been determined as Lower Llanvirnian. If one suggests a similar age for the Leka conglomerate, this means that the underlying old complex must be of pre-Llanvirnian (Skiddavian?) age.

TECTONICS AND METAMORPHISM

The orogenic pressure that forced the sediments of the younger series into a narrow, NE-SW-trending syncline has, at least partly, also affected the substratum. This is proved by the fact that the conglomerate in the area west-southwest of Havneholmen underlies a saussurite gabbro belonging to the old complex, which indicates that the southeastern limb of the syncline has been inverted towards the northwest. Evidence of strong folding pressure, resulting in local obliteration of the conglomerate structure, is also found here. In most other places, the conglomerate is surprisingly well preserved.

The metamorphism of the rocks of the Leka district has obviously taken place within the stability range of the greenschist facies. While the alteration of the gabbro is always complete, relics of monoclinic pyroxene may sometimes be found in the serpentine. No traces of the primary olivine are, however, any longer present. The normal saussurite gabbro, containing an actinolitic amphibole as the chief dark mineral, may locally pass over into a schistose variety composed essentially of chlorite (antigorite), calcite and albite.

As to the rocks of the younger series, recrystallization has been complete, or almost so, in the phyllite and limestone, while in the conglomerate and sandstone it is usually limited to the fine-grained matrix.

THE BASEMENT COMPLEX AND THE CALEDONIAN ZONE OF DEFORMATION

Within the "Vestrand" region, of which most of the area investigated is an integral part (Fig. 1), KJERULF (1871, 1876, 1879) distinguished between the following three structural units: (1) a pre-Cambrian supracrustal rock system, termed "grunnfjell", (2) a plutonic association, characterized by various types of foliated granite which in huge masses break through the old rock system, and (3) narrow synclines of Cambro-Ordovician rocks, representing more or less isolated lateral branches of the Trondheim synclinorium proper. According to KJERULF, the said granite masses penetrate the Cambro-Ordovician rocks as well.

About 25 years later, SCHETELIG (1913) not only adobted the idea of the younger age of the "Vestrand" granite, but also maintained that the great bulk of the "grunnfjell" of this region actually represented gneissified Caledonian igneous rocks with remnants of altered sediments, all of which had been intruded by Caledonian granites. At the same time, however, he was aware of the possible existence of real pre-Cambrian gneisses and other rock types within the "Vestrand" region. A reply was given by REUSCH in a paper which appeared the following year (REUSCH, 1914). In this paper, REUSCH definitely rejected SCHETELIG's hypothesis, arguing that there was nothing within the region concerned that might justify a distinction between pre-Cambrian rock complexes and younger intrusives.

The idea of SCHETELIG, in a modified form, has subsequently been advocated by several geologists, particularly by HOLTEDAHL, who in his writings has emphasized the role of Caledonian granitization and migmatization processes in the geological development of the

"Vestrand" and the adjoining eastern region (HOLTEDAHL, 1938a, 1938b, 1944; BARTH, 1938; RAMBERG, 1943).

Nevertheless, as a result of field investigations carried out by the present writer in the critical western and central parts of northern Trøndelag, the existence here can now be proved, in direct conflict with the hypothesis of HOLTEDAHL *et al.*, of an old, pre-Cambrian rock complex, representing the deformed but otherwise — mineralogically and structurally — unaltered basement of the unconformably overlying system of folded and metamorphosed Cambro-Ordovician supracrustal rocks. This means that there can be no justification for the idea that Caledonian orogenic movements can have affected the basement complex in the said region to such a degree as to have given the rocks in question a "Caledonian" stamp, nor is there any basis for the assumption that Cambro-Ordovician supracrustals may have been incorporated in the basement complex with the final result of having lost their identity by strong granitization processes. No doubt, the only effect of the Caledonian orogeny upon the basement complex was the deformation of the surface of contact between this complex and the superimposed younger sedimentary and volcanic rocks, with the downfolding of the latter into deep NE-SW-trending synclines as the most distinctive feature.

The chief problems of the area may be stated as follows:

I. The boundary relations of the basement complex to the overlying Cambro-Silurian rock system.

II. The general structural situation of the basement complex, and its dependence or independence of Caledonian tectonics.

III. Differences in the lithological and petrological development of the two tectonic units.

I. In the current view, there exists, broadly speaking, absolute conformity between the Cambro-Ordovician supracrustals and the rocks of the basement complex appearing within the central parts of the Caledonian orogenic zone in southern Norway, a view which was originally also shared by the writer. However, difficulties in explaining certain features of the tectonics of the region under consideration made it necessary to undertake a closer investigation of the boundary lines between the two rock systems, for which reason thorough field studies were commenced in the summer of 1950.

The results achieved contradict the hypothesis of HOLTEDAHL, RAMBERG, *et al.* Thus, the junction between the basement complex and the overlying formations could in many cases be readily recognized as an unconformity, whilst in other cases the same conclusion was arrived at by areal mapping (Pl. III). Along most of the western border of the Bindal syncline, the Cambro-Ordovician schists are in immediate contact with members of the acid plutonic association of the basement complex, a boundary relation that has the character of a nonconformity (BILLINGS, 1942, p. 243). Only quite exceptionally may the unconformity be indicated by the presence of basal conglomerates (see p. 366).

Previously (pp. 371, 399), reference has been made to the remarkable fact that Cambro-Ordovician sedimentary strata may sometimes be entirely lacking along the junction with the basement complex, their place then being occupied by thick layers of altered basic and/or acid lavas. Along the northern border of the Snåsa syncline, low-grade basic volcanic rocks (greenstone, greenschist) form a zone of varying breadth, extending from Lake Holden vatn to a point a little southwest of Lurudal railway station (Fig. 10). A much smaller zone of rocks of this type occurs in a corresponding stratigraphical position in the district just north of Steinkjer. In the northwestern part of the Bindal syncline, a thick zone of metadacite and metabasalt is in immediate contact with the basement complex from a point northwest of Foldereid church to Sør fjord (Fig. 11).

Two explanations are possible regarding this puzzling boundary situation: (a) the junction is an unconformity; (b) the contact is a secondary structural feature. The present writer at once rejects the latter interpretation as being utterly untenable. Actually, there is no field evidence forthcoming to support the idea that fault or thrust movements have taken place along the junction between the basement complex and the younger rock system in any of the districts mentioned above; likewise, similar movements are unknown from the other parts of the area. The safe conclusion, therefore, must be that the junction between the two tectonic units is an unconformity.

II. The general structural situation of the basement region appears from the map, Pl. III, which shows a rather intricate tectonic picture, with huge masses of granite and granodiorite breaking through the folded and metamorphosed supracrustal rocks in a catastrophic manner. A characteristic detail is the domical shape of some of the larger granitic bodies. The contacts are broadly concordant with the foliation of the country rocks. Another significant feature is that the planar structures of the granitic plutons are always parallel to the boundary surfaces between these plutons and the enclosing rocks, indicating that the planar structures are primary and not secondary.

Valuable information regarding the true nature of the planar structures of the granitic plutons may be obtained also from the relation of inclusions of country rock to the foliation, and from the appearance of granite-filled shears and pegmatite dikes.

The inclusions, when present, occur as thinner and thicker flake-like masses, which are usually oriented parallel to the foliation of the granite and granodiorite. Exceptions to the rule are rarely observed. An illustration to the latter case is given in Fig. 8. The locality in question is situated on the northern slope of the mountain of Kjøringsvassfjell, in the Foldereid district. The inclusion, which is oriented with its major axis at almost right angles to the foliation of the pluton (a biotite granite), is a dark, medium-grained, hornblende-biotite-bearing lime silicate gneiss. However, what is important in this connection is the fact that the foliation of the granite is deflected near the border of the xenolith without cutting across the gneiss mass. The latter clearly has its own schistosity, which is unrelated to the foliation of the pluton. Here, too, there can be no doubt as to the primary origin of the planar structure of the granite.

The granite-filled shears and associated pegmatite dikes which intersect the foliation of the granitic plutons, must have been formed in a late stage of the consolidation of these plutonic masses (p. 360). Since both shears and dikes bear a definite relation to the last plastic yielding of the plutons, and therefore also to the regional stress which produced the last folding within the orogenic zone, the conclusion seems inevitable that the foliation is a primary structural feature.

Linear structures are frequently developed both in the granitic plutons and in the adjacent country rocks. However, as these structures have not been the object of systematic investigations, a discussion of this feature and its bearings on the tectonics of the region is quite beyond the scope of the present paper.

What then may be inferred from the above account of structural facts? In the writer's opinion, the assumption of a Caledonian age for the basement complex is disproved by nature itself. There are two important grounds for such a statement: firstly, the existence of an unconformity between the basement complex and the overlying Cambro-Ordovician formations; and secondly, the primary character of the planar structures of the acid plutons in the basement complex. It is highly improbable that the movements connected with the Caledonian orogeny could have impressed a new structure upon the pre-existent granitic plutonic rocks without leaving a trace of the old magma tectonics. Even more unacceptable is the opinion arrived at by some geologists that the said acid plutons may owe their origin to strong Caledonian granitization processes. This would necessarily imply a much higher (ultrametamorphic) temperature of development for the rocks of the basement complex than for the rocks of the Cambro-Ordovician system, despite the fact that the region occupied by the basement complex lies tectonically higher in the mountain chain than do the lowest parts of the younger formations. As, in addition, the various plutonic and nonplutonic rocks of the basement complex differ strikingly from those of the Cambro-Ordovician system, we may conclude that the former cannot reasonably owe their origin to Caledonian rock-forming processes. There is no doubt that the rocks of the basement complex existed in their present state long before the beginning of the Cambrian.

III. The nonplutonic rocks of the basement complex comprise both metasediments and metavolcanics. The metasediments are represented mainly by different types of gneiss, viz. quartzofeldspathic gneiss, micaceous gneiss and lime silicate gneiss. Other rock types, occurring in relatively small quantities, are quartzite, quartz schist, mica schist, and crystalline limestone and dolomite. In regard to the metavolcanics, only basic types have been observed (metabasalt). Most of the gneisses are interpreted as regionally metamorphosed arenaceous sediments, e. g. arkosic sand, calcareous sand and clayey sand, while some of the lime silicate gneisses may have originated from marly sediments. Metamorphosed arkosic sediments, now found as massive gneisses light-grey to grey in color, are particularly abundant in the southern and southeastern districts of the basement region, where, also, the association metabasalt-quartzofeldspathic gneiss is commonly observed. From a lithological point of view, therefore, the basement complex forms a striking contrast to the Cambro-Ordovician rock system, with its thick strata of mica schist (in part lime silicate-bearing) and crystalline limestone, representing metamorphosed argillaceous and calcareous sediments.

The following rock types are regarded as specific of the basement complex: (a) sillimanite-almandite-bearing and sillimanite-cordierite-bearing micaceous gneiss; (b) various types of gneiss carrying one of the Ca-free amphiboles cummingtonite and anthophyllite; (c) norite and olivine hyperite; (d) widely distributed members of the granite-granodiorite family containing a hornblende of the hastingsite series as the characteristic dark mineral.

Rocks which conform more or less in mineral composition to members of groups (a), (b) and (c), cited above, are also known from the pre-Cambrian of southernmost Norway (BUGGE, 1943).

Two causes may be of importance in any attempt to explain the general failure of the rocks of the basement complex to respond to the changes in the physical conditions of the crust which took place in this region during the Caledonian orogeny. Firstly, there is every indication that the basement complex acted simply as one connected mass, which was sufficiently "rigid" to prevent the rocks in question being involved in differential movements and a consequent obliteration of the original structures. Secondly, the reaction rate was evidently not high enough to render chemical reactions effective in transforming the various mineral assemblages of the basement complex into stable ones, corresponding to the new pressure-temperature conditions in the Caledonian orogenic zone. Contributory causes may have been the relative "dryness" of the rocks of the basement complex, and the absence of differential movements, as stated above.

SUMMARY AND CONCLUSIONS

The rocks of the area investigated belong demonstrably to two distinct tectonic units: (1) an old rock system (termed the basement complex) which is part of a pre-Cambrian mountain chain, and (2) a younger (Caledonian) system of folded and metamorphosed early Paleozoic geosynclinal rocks with intrusives. The younger rock system rests on the older one with a profound unconformity. In many places, therefore, the base of the younger formations may truncate the structures of the old rock system at any angle.

The first section of the present paper deals with the rocks of the basement complex. The quartzite and quartz schist, the mica schist, the various types of gneiss and the marbles are interpreted as regionally metamorphosed geosynclinal sediments. The gneisses, which are the predominant rocks, probably originated from arenaceous and marly sediments. Metamorphosed basaltic lavas have been described from various parts of the basement region, but they are more widely distributed only in the southern and southeastern districts of this region, where the association metabasalt-quartzofeldspathic gneiss is a characteristic lithological feature. Altered acid lavas, on the other hand, have not been encountered within the basement complex.

The supracrustal rock system has been intruded by plutonic masses of basic and ultrabasic composition. The latter commonly appear in the shape of small lentoid bodies, which are concordant with the structure of the enclosing rocks. The ultrabasic masses are always completely serpentinized, the common minerals being antigorite and talc. The basic plutonic rocks comprise noritic and hyperitic types.

In the later orogenic phase, the geosyncline was laid in deep folds, which seem broadly to have had a ENE-WSW to NE-SW trend. It is evident, however, that the original fold structures have been more or less modified by the subsequent intrusion of immense quantities of granitic magmas. During this mighty upsurge of acid magmatic melts, the geosynclinal zone was split into smaller parts, represented by strongly contorted belts of metamorphosed supracrustal rocks.

A vast space of time presumably lies between the old, pre-Cambrian orogeny and the incipient development of the Caledonian geosyncline. The Cambro-Ordovician sedimentary series often begins with a relatively thin layer of a type of mica schist representing metamorphosed argillaceous deposits poor in lime. Near the base may occur thin beds of quartzite, while conglomerate is very rarely found. These rocks are succeeded by a much thicker zone of calcite- and lime silicate-bearing mica schists, with subordinate crystalline limestone or (less frequently) dolomite. Laterally, changes of facies may be rapid. This, for instance, applies to the conditions along the western flank of the Bindal syncline, where the changes in the petrography of the metasediments, from mica schists in the south to lime silicate gneisses and marbles in the north, may be interpreted as due to changes in the lithology of the original sediments, from clayey facies in the south to marly or true calcareous facies in the north.

Evidence of early Ordovician volcanic activity is found in various parts of the Caledonian orogenic zone in Norway. The oldest volcanic rocks are represented by low-grade basic lavas and related pyroclastic sediments (greenstone and greenschist), which may here and there be associated with acid lava types (quartz-keratophyre). In northern Trøndelag, volcanic rocks of this kind appear in the Snåsa syncline, in the southernmost part of the Bindal syncline, and in the Grong district.

Probably slightly younger than these rocks is a series of basaltic and dacitic (rarely andesitic) effusives, occurring as a well-defined stratigraphical horizon in the western part of the Bindal syncline, and conformably overlying the older sediments of that region. Farthest north, however, on the west side of the Kolbotn inlet, the volcanic rocks overlap the pre-Cambrian basement along a junction which is regarded as primary. The maximum thickness of the effusive series is — in the Foldereid district — estimated to about 2000 m. Although subjected to relatively strong regional metamorphism, the said lavas have usually retained much of their original texture and mineral composition. Occasionally intercalated layers of metamorphosed sediments may be found, such as quartzite, mica schist, gneiss and crystalline limestone.

This volcanic series is overlain by a series of metamorphosed sediments, made up of quartzite and mica schist, various types of gneiss, and crystalline limestone. The two series (within the map area, they are apparently known only from the Bindal syncline) constitute the upper part of a thick succession of supracrustal rocks which accumulated in Cambro-Ordovician times under geosynclinal conditions.

The oldest Caledonian intrusive rocks found within the map area are probably represented by members of the peridotite family. These rocks, which may be more or less serpentinized, usually occur as small lens-shaped bodies. A large body of serpentine is found in the Leka district. Gabbro, generally somewhat saussuritized, appears in large masses only in the Leka district and in the area east of the southernmost part of the Bindal syncline. Apart from these rocks, quartz-diorite, trondheimite and granodiorite occur in bodies of varying size and shape.

During an early stage of the Caledonian orogeny, which may be identical with the Trondheim disturbance (at the transition interval between the Skiddavian and Llanvirnian epochs), the stratified rocks were tilted and possibly slightly folded and metamorphosed. Simultaneously, parts of the geosyncline were elevated above sea level and thereby exposed to the forces of erosion. It is possible that the debris formed by the destruction of the rising land masses of that time may correspond to the great thicknesses of conglomerate and sandstone which appear in the Snåsa syncline, in the Grong district and in the Leka district. Tentatively, this conglomerate and sandstone division may be correlated with the lower part of the Lower Hovin series in the Trondheim region.

From other areas in the Caledonides of Norway, we know that there must have been several such minor cycles of alternating renewed sinking and compression of the geosynclinal belt (followed by erosion and sedimentation) in the course of Ordovician and Silurian times. Towards the end of the Silurian period, during the main phase of the Caledonian orogeny, the geosyncline was strongly compressed, at the same time as the folded masses rose to mountainous proportions. In the Bindal syncline the folding movements were accompanied by intense plutonic activity, through which magmas of granitic and granodioritic composition protruded in large quantities. In contrast to this, intrusives of the same age and petrographical character are entirely absent from both the Snåsa syncline and the Leka district. There is, further, reason to believe that in a later orogenic phase, characterized by strong compressive stresses, the central part of the Bindal syncline, represented mainly by the large consolidated massif of granite and granodiorite, was forced to move up along steeply dipping thrust faults, while the surrounding rock masses remained essentially stationary.

In the last section of the present paper, the relation of the basement complex to the Caledonian zone of deformation is discussed. The conclusion reached is that the rocks of the basement complex owe their structural and mineralogical development to pre-Cambrian orogenic movements and to the physical conditions of the crust of that time — that, in other words, no relationship exists between the basement complex and the folded and metamorphosed younger formations. The only effect of the Caledonian orogenic movements upon the basement complex has been a deformation of the surface of contact between this complex and the overlying Cambro-Silurian rock system along axes of folding that may be more or less prescribed by the older, pre-Cambrian orogeny.

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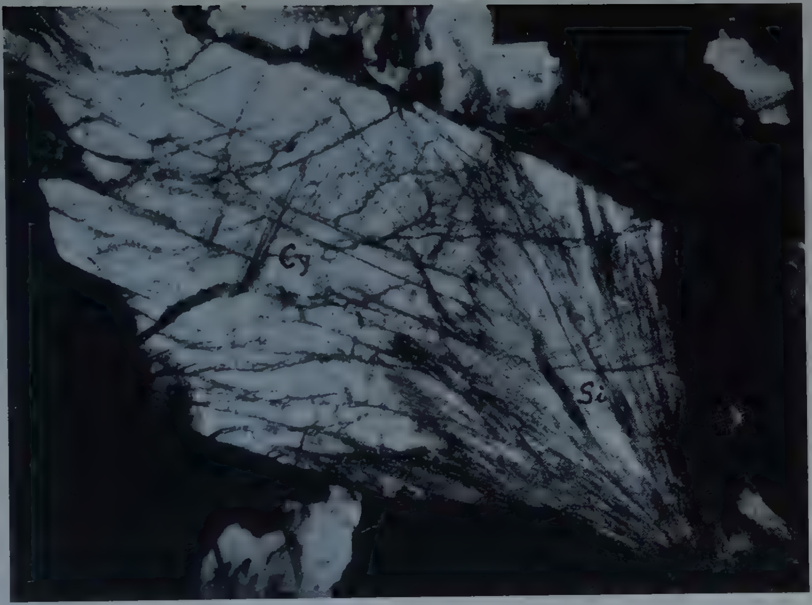


Fig. 1. Micaceous gneiss with sillimanite (Si) and cyanite (Cy). From the islet of Purkholmen near Abelvær. Crossed nicols. x 13.

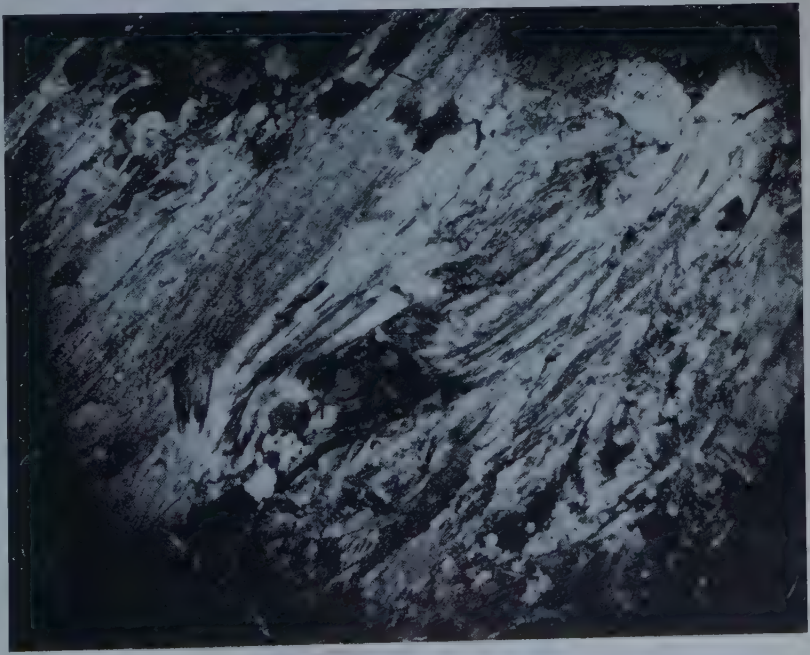


Fig. 2. Cordierite-sillimanite-bearing micaceous gneiss. From the western slope of the mountain of Høgråna, east of Rørvik. Crossed nicols. x 12.

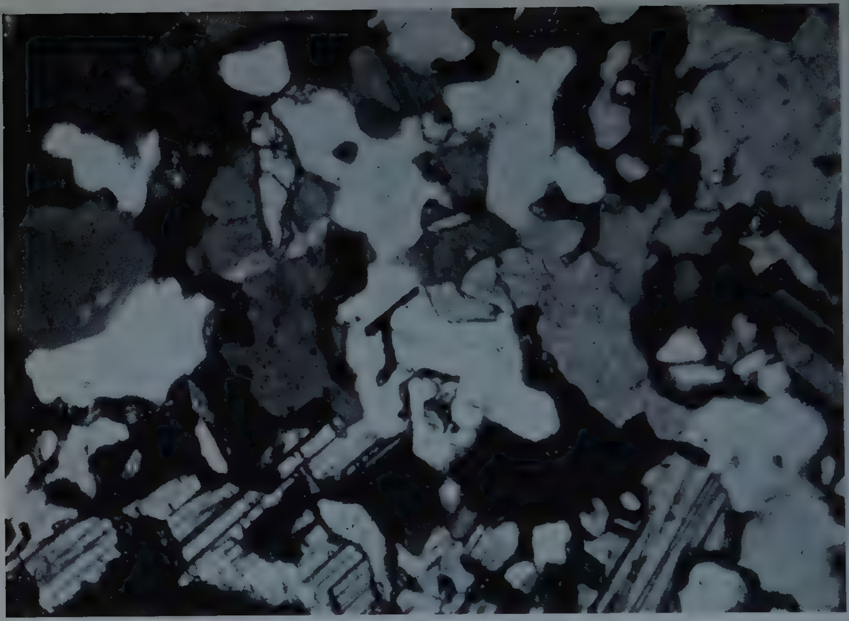


Fig. 1. Lime silicate rock with anorthite (An_{95}), diopside, grossularite, zoisite and quartz. From the island of Krokøya near Abelvær. Crossed nicols. x 70.

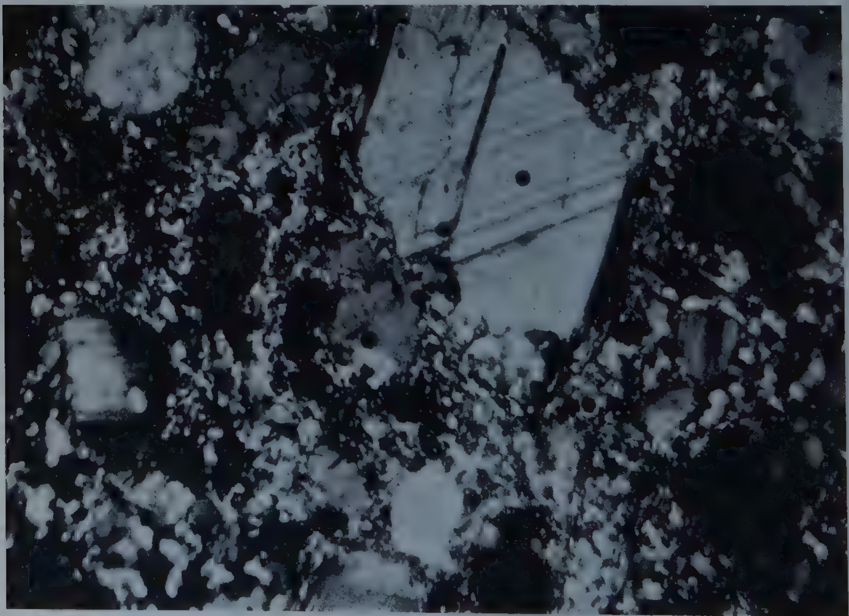


Fig. 2. Metadacite with phenocrysts of plagioclase (An_{40}). From the western slope of the mountain of Holandsfjell, east of Foldereid. Crossed nicols. x 37.

PLATE III

Geological map of the Northwestern part of Northern Trøndelag

By Tor Birkeland

CAMBRO-SILURIAN

▨ The Snåsa syncline

▤ The Bindal syncline

▥ The Leka district

PRE-CAMBRIAN
(The Basement Complex)

Sedimentary rocks

▤ Quartzofeldspathic gneiss (with quartzite and quartz schist)

▨ Micaceous gneiss (with mica schist)

▨ Lime silicate gneiss (with crystalline limestone)

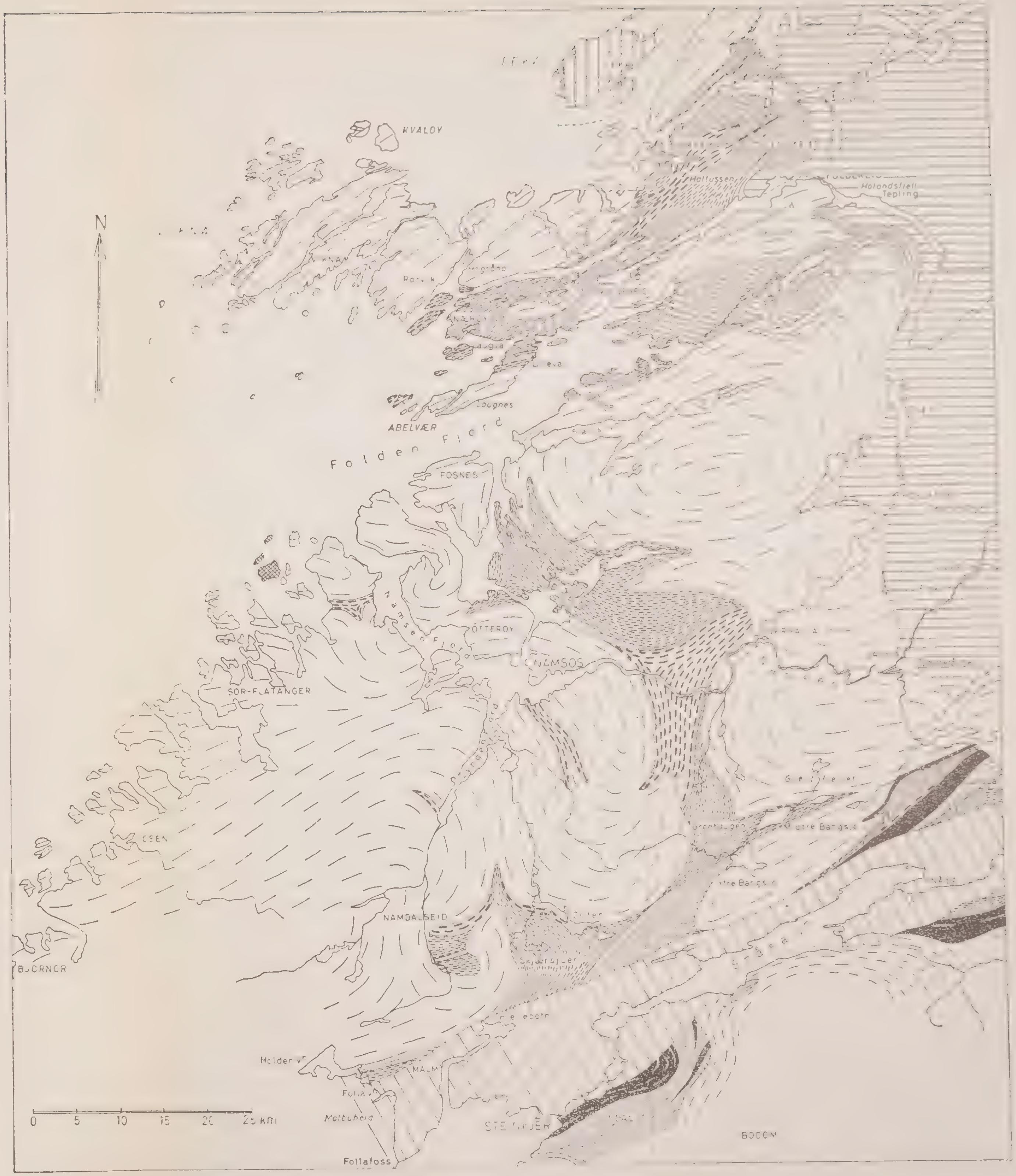
Igneous rocks

■ Metabasalt

▦ Gabbro

▭ Granite and granodiorite

▭ Fine-grained, porphyritic granite



NOTISER

First Circular announces

XXI International Geological Congress.

Copenhagen, Denmark. — August 15–25, 1960.

The First Circular announcing the XXI INTERNATIONAL GEOLOGICAL CONGRESS has been issued by the five Nordic nations which will be hosts to the geologists of the world in 1960. The formal sessions of the Congress will be held at the Mineralogical-Geological Museum of the University of Copenhagen in Denmark from August 15-25, 1960, according to the invitation issued jointly by the geologists of Denmark, Finland, Iceland, Norway and Sweden.

Forty-eight pre-Congress field excursions are listed in the First Circular, including trips to all of the countries represented on the Organizing Committee. There will be an opportunity to study classic areas of hard rock geology and equally classic sedimentary sections. Many of the trips will offer great scenic appeal as well as geologic intrigue. For example, one excursion will study the geology along the north coast of Norway with travel principally by boat. Pre-Congress excursions to West Greenland and to Iceland will be available to limited groups. These two trips will not be repeated as post-Congress excursions. There will be 43 post-Congress excursions, a large number of which will repeat pre-Congress itineraries.

The First Circular lists 20 subjects selected for discussion at the 21st Congress.

The closing date for titles and abstracts to be submitted for papers to be presented at the XXI IGC is April 1, 1959. The complete text of papers must be submitted, ready for publication on or before September 1, 1959. A 5000 word limit is imposed on papers submitted, and the Organizing Committee is urging that papers be submitted and presented in English, although, as usual, there are six official languages accepted for the Congress.

The Organizing Committee for the XXI International Geological Congress is made up of geologists of the five Nordic host countries

President is professor Arne Noe-Nygaard, Denmark, and General Secretary is state geologist Theodor Sorgenfrei, Denmark.

Copies of the First Circular have been supplied to the Universities, Geological Institutes, Geological Surveys and Geological Societies all over the world for distribution between the geologists, but copies may still be obtained by writing to the

XXI INTERNATIONAL GEOLOGICAL
CONGRESS 1960
The Organizing Committee
Mineralogisk Museum
Øster Voldgade 7
Copenhagen K., Denmark

(Geologists in U.S.A. and Canada may write to Congress Travel, c/o. American Geological Institute, 2101 Constitution Avenue, N.W., Washington 25, D.C., U.S.A.).

Arne Noe-Nygaard.

International Union of Crystallography.

Den femte generalforsamling og internasjonale kongress vil bli holdt i Cambridge, England, i tiden 14.—24. august 1960. Kongressen vil vare ca. en uke fra 15. august. Resten av tiden tenkes benyttet til to symposier. Formann i kongress-komiteen er Dr. W. H. Taylor, Cavendish Laboratory, Cambridge. Nærmere detaljer vil bli kunngjort fra tid til annen.

Ivar Oftedal.

NORSK GEOLOGISK FORENING

Møte nr. 376, 24. april 1958.

Til stede 21 medlemmer og 1 gjest.

Direktør *Sven Føyn* redegjorde for Kommisjonen for det geologiske-verdenskarts møte i Paris 31/3—12/4—1958.

Foredrag av vitenskapelig assistent *Paul Reitan:*
«En tolkning av petrografiske og petrokjemiske variasjoner i sidebergarten ved 3 pegmatittganger».

I ordskiftet etter foredraget deltok:
T. Barth, Chr. Oftedahl, B. Dietrichson, O. A. Broch, H. Major T. Strand og foredragsholderen.

Møte nr. 377, 29. mai 1958.

Til stede 13 medlemmer og 4 gjester.

Følgende innvalg ble godkjent:
428. Mr. Bertram Arthur Owen Randall, Department of Geology, King's College, Newcastle. Foreslått av T. W. Barth og H. Neumann.
429. Fil.mag. Ebbe Zachrisson, Mystan, Pålstorp. Foreslått av T. Strand og N. Spjeldnæs.

Foredrag av Professor *Einar Høyland:*
«Paleotemperaturer».

I ordskiftet etter foredraget deltok:
H. Rosendahl, B. Dietrichson, N. Spjeldnæs og foredragsholderen.

GEOLOGNYTT

Norges geologiske undersøkelse.

Cand. real. SVEN FÖYN fratrådte som direktør pr. 1. august 1958.

Dr. philos. HARALD BJØRLYKKE tiltrådte som direktør fra samme tid

Statsgeolog ARTHUR O. POULSEN fratrådte pr. 1. oktober 1958 ved oppnådd aldersgrense.

Laboratorieingeniør BRYNJOLF BRUUN fratrådte pr. 1. oktober 1958.

Cand. real. FINN J. SKJERLIE fratrådte som midlertidig statsgeolog II pr. 31. desember 1957.

DWIGHT F. CROWDER, M. Sc., fratrådte som midlertidig statsgeolog I pr. 15. mai 1958.

Stud. real. LISBETH REH fratrådte som midlertidig vitensk. assistent pr. 30. juni 1958.

Cand. real. THOR LORCK SVERDRUP ble ansatt som midlertidig statsgeolog II fra 1. februar 1958.

PAUL H. REITAN, B. A., ble ansatt som midlertidig statsgeolog II fra 16. mai 1958.

Statsgeolog TORE GJELSVIK har fått ett års permisjon fra 16. mars 1958 for å organisere uranleting i Burma.

Statsgeolog PER HOLMSEN har fått forlenget permisjon til 1. juli 1959 for å fortsette i stillingen som geolog ved Norges statsbaner.

Statsgeolog STEINAR SKJESETH er fra 1. oktober 1958 beskikket som statsgeolog I.

N.G.U.'s 100 års jubileum ble feiret den 9. mai 1958. Det ble holdt et jubileumsmøte om formiddagen med etterfølgende åpning av en jubileumsutstilling i «Håndverkeren». H M Kongen var til stede. Om aftenen ble det gitt en middag i Oslo Militære Samfund for N.G.U.'s personale og en del innbudte representanter for administrasjon og forskning. Representanter for de tilsvarende institusjoner i de øvrige nordiske land var også til stede. Utstillingen, som var meget godt besøkt, var åpen for publikum 10. — 14. mai.

Universitetet i Oslo.

Institutt for geologi.

Mineralogisk institutt, Geologisk institutt og Paleontologisk institutt er slått sammen til *Institutt for geologi.* De tidligere institutter benevnes avdeling A, B, C, og en ny avdeling D er opprettet for paleobotanikk (styrer Professor O. A. HØEG.).

12. februar 1958 ble den nye bygning på Blindern for Institutt for geologi overtatt av Universitetet. Bygningen er reist for midler gitt av Norges almenvitenskapelige forskningsråd.

Universitetsstipendiat NILS SPJELDNÆS ble av Det akademiske kollegium kreert til doctor philosophiæ i desember 1957, etter å ha forsvart sin avhandling: «The Middle Ordovician of the Oslo Region, Norway. 8. Brachiopods of the Suborder Strophomenida.»

SPJELDNÆS er med stipendium fra Norges almenvitenskapelig forskningsråd reist til U.S.A. for å studere ordovicisk stratigrafi og fauna.

Cand. real. OLAF VILHELM HAGBERG er fra 1. oktober 1958 ansatt som amanuensis ved Institutt for geologi, med plikt til å forestå instituttets kjemiske laboratorium og gi undervisning i silikatanalyse for hovedfagstuderende i geologi.

Mineralogisk-Geologisk Museum.

Dr. R. MORTON, Nottingham, er ansatt som midlertidig vitenskapelig assistent.

Cand. real. K. S. HEIER, universitetsstipendiat fra 1/8—1958.

Til forskningsprogrammet *Norges mineraler* (Norges teknisk-naturvitenskapelige forskningsråd) er ansatt:

Dr. F. M. VOKES.

Ingeniør B. BRUUN.

Følgende gjestende forskere arbeider ved museet i året 1958/59:

Fullbrightstipendiat N. CARTER (petrografi og tektonikk ved Tinnsjøens S-ende).

Professor R. V. DIETRICH, Fullbrightstipendiat (Petrografi i Kristiansandtrakten).

Dr. S. DIVLJAN, Jugoslavia, norsk statsstipendiat (Pegmatitter med solsten i Tvedestrandstrakten).

Engelsk stipendiat W. E. ELDERS, Newcastle (Petrografi og tektonikk i Bamble-formasjonen).

Professor A. J. FRUEH, stipendiat betalt av U.S. Air Research and Development Command (Strukturer av sulfider).

Engelsk stipendiat B. PLAYLE, Nottingham (Permsedimenter, eldste vulkanisme i Asker).

Sveitsisk stipendiat J. P. SCHAER, Neuchâtel (Tektonikk omkring grensen mellom Bamble- og Telemarksformasjonene).

Eksamener.

Ved *Universitetet i Oslo* er matematisk-naturvitenskapelig embetseksamen med hovedfag mineralogi og petrografi fullført av:

THOR LORCK SVERDRUP i høstsemesteret 1957. Hovedoppgave: «En mineralogisk og petrografisk undersøkelse av en sydnorsk pegmatitt i kvartsmonzonitten farsunditt ved Rømteland i Vest-Agder fylke.»

KNUT ØRN BRYN i høstsemesteret 1958. Hovedoppgave: «En geologisk undersøkelse av bergartene på søndre del av kartblad Essandsjø.»

Ved *Universitetet i Bergen* av:

INGE BRYHNI i vårsemesteret 1958. Hovedoppgave: «Petrografisk og tektonisk beskrivelse av et område omkring Eikefjord, Sogn og Fjordane fylke».

Geofysisk Malmleting.

Cand. real. FINN J. SKJERLIE er fra 1. januar 1958 ansatt som ved Geofysisk Malmleting, Trondheim.

MEDLEMSLISTE

à jour oktober 1958.
¹: korresponderende medlem.
*: livsvarig medlem.
Tallet i parentes er innvalgsåret.
(S), stifter (18. februar 1905).

*Adamson, Olge J., dr. Postboks 42, Smedstad pr. Oslo. (1945).
Ahlmann, Hans W:son, professor, Fregattvägen 6, Gräsdal, Stockholm S.V., Sverige. (1919).
Andersen, Bjørn, univ.stip. Geologisk institutt, Blindern, Oslo. (1952).
Asklund, Bror, professor, Sveriges Geologiska Undersökning, Stockholm 50. (1938).
*Bache, Laura, lektor. Eiksbo, vei 509, Eiksmarka, Røa, Oslo. (1931).
*Backlund, Helge, professor. Mineralogisk-geologiska Institutionen, Uppsala 1. (1919).
Baker, Donald, B.Sc. The Ohio Oil Company, P. O. Box 269, Littleton, Col., U.S.A. (1951).
Bakken, Asbjørn, lektor. Voss Landsgymnas, Voss. (1954).
*Barth, Tom, F. W., professor. Geologisk museum, Oslo NØ. (1921).
Bergersen, Birger, statsråd. Anton Schjøthsgt. 13, Oslo. (1921).
Bertheau-Hansen, Chr., bergingeniør. Norges geologiske undersøkelse, Oslo NV. (1942).
Birkeland, Tor, lektor. Avaldsnesgt. 36, Stavanger. (1946).
Bjerrum, Lauritz, direktør. Norges geotekniske institutt, Blindern, Oslo. (1952).
*Bjørlykke, Harald, direktør. Norges geologiske undersøkelse, Oslo N. V. (1923).
Boughton, Eric. Hay Tor, 921 Harrow Rd., Wembley, Middlesex, England. (1932).
*Broch, Olaf Anton, statsgeolog. Norges geologiske undersøkelse, Oslo NV. (1920).
*Bruun, B., ingeniør. Geologisk museum, Oslo NØ. (1938).
Bryhni, Inge, cand.real. Geologisk institutt, Universitetet i Bergen. (1955).
*Bryn, Knut Ørn, cand.real. Borgenvn. 39, Vindern, Oslo. (1956).
Brøndbo, Knut, bergingeniør. A/S Titania, Hauge i Dalane. (1955).
*Braastad, Johan, dr. Postboks 808, Oslo. (1913).
Bugge, Arne, dr. Utsiktsveien 21, Stabekk. (1914).
*Bugge, Carl, direktør, Håkon den gode's vei 12, Vindern, Oslo. (S).

*Bugge, Jens, professor, Geologisk Institutt, N.T.H., Trondheim. (1940).

*Bulman, O. M. B., professor. Sedgwick Museum, Cambridge, England. (1951).

Bølviken, Bjørn, ingeniør. Statens Råstofflaboratorium, Postboks 1078, Trondheim. (1958).

*Callisen, Karen, dr. Mineralogisk og Geologisk Museum, Østervoldgade 7, København K. (1917).

Cameron, Richard. Dept. of Geology, Ohio State Univ., Columbus 10, Ohio, U.S.A. (1956).

*Carstens, Harald, geolog. Saxenborg, Trondheim. (1949).

Caster, Kenneth, professor. Dept. of Geology and Geography, University of Cincinnati, Cincinnati, Ohio, U.S.A. (1953).

*Chapman, Charleton, A., professor. University of Illinois, Urbana, Ill., U.S.A, (1949).

*Chen Kwan Yuan, B. Sc. Geological Institute, National Peking University, Peking, Kina. (1951).

Collini, Bengt, fil.lic., laborator. Kungl. Lantbrukshögskolan, Institutionen för Marklära, Uppsala 7, Sverige. (1949).

Craig, H. B., dr. Dept. of Geology, University, Chicago 37, Ill., U.S.A. (1949).

*Crowder, Dwight, dr. Mineral Deposits Branch, U.S. Geological Survey, Denver Federal Center 25, Denver, Colorado, U.S.A. (1958).

*Dahl, Eilif, cand. real. Botanisk institutt, Norges Landbrukshøgskole, Vollebekk. (1946).

Dahl, Erling, ingeniør. Skogveien 1, Notodden. (1945).

Dahlström, Elis, dr. Lundberg Explorations Ltd. AB, Lindhagensgatan 132. Stockholm K., Sverige. (1945).

Danielsen, Anders, konservator. Botanisk museum, Bergen. (1949).

*Devore, George W., dr. Dept. of Geology, University, Chicago 37, Ill., U.S.A. (1948).

Dietrichson, Brynjulf, bergingeniør. Institutt for geologi, Blindern, Oslo. (1917).

Donnay, J. D. H., professor. Johns Hopkins University, Baltimore 18, Maryland, U.S.A. (1937).

*Dons, Johannes A., konservator. Geologisk museum, Oslo NØ. (1941).

Dybdahl, Ivar, bergingeniør. A/S Titania, Hauge i Dalane. (1958).

*Eckermann, Harry von, professor. Edeby pr. Ripsa, Sverige. (1937).

*Edelman, Nils, dr. Bolidens Gruv AB., Boliden, Sverige. (1956).

Egeberg, F. P., bergingeniør. Rådhusgata 5b, Oslo (1939).

Einevoll, Ola, landbrukskandidat. Norges Landbrukshøgskole, Vollebekk. (1957).

Elliott, Robert B., dr. Department of Geology, The University, Nottingham, England (1954).

Enkovaara, Antti, magister. Oulainen, Finnland. (1947).

Eriksen, Edv. Andreas, bergingeniør. Munkedamsvn. 81c, Oslo (1945).

*Eskola, Pentti, professor, Min.-geol. Inst., Universitetet, Helsingfors. (1919).

Espeland, Margaret, B. Sc. Hus 2, Vei 3672, Nordstrandhøgda, Oslo (1950).

*Falkenberg, Otto, ingeniør. Priorveien 7, Smestad, Oslo. (1914).

Faust, G. T., dr. U.S. Geological Survey, Washington 25 D.C., U.S.A. (1956).

*Feyling-Hanssen, Rolf, statsgeolog. Norges geologiske undersøkelse, Oslo NV. (1950).
*Fuster, José M., professor. Museo National de Sciencias Naturales, Madrid, Spania. (1957).
*Fægri, Knut, professor. Botanisk museum, Bergen. (1935).
Færden, Johannes, geolog. A/S Norsk Bergverk, Chr. Augustgt. 15, Oslo. (1948).
*Føyn, Sven, lektor. Sørkedalsveien 93d, Oslo — Smestad. (1932).
Garthus, Torbjørn, lærer. Garthus, Valdres. (1943).
Gavelin, Sven, professor. Mineralogiska Institutet, Stockholms Högskola, Stockholm, Sverige. (1954).
Gillberg, Gunnar, fil. lic. Stockholms Högskola, Stockholm, Sverige. (1952).
*Gjelsvik, Tore, statsgeolog. Evjebakken 18, Sandvika. (1945).
Gjems, Odd, amanuensis. Norges Landbrukshøgskole, Vollebekk. (1958).
Gjessing, Just, amanuensis. Geografisk institutt, Blindern, Oslo. (1953).
*Gleditsch, Chr., geolog. Bentsegt. 10, Oslo, (1941).
Graff-Petersen, Poul, mag.scient. Mineralogisk Museum. Østervoldgade 7, København K. (1957).
*Green, John C. dr. Department of Geology, University of Minnesota, Duluth 11, Minn., U.S.A. (1954).
Grenness, Johannes, ingeniør. Statens råstofflaboratorium, Østmarka, Trondheim. (1945).
*Grip, Erland, fil. lic. Boliden, Sverige. (1938).
*Grønlie, Arne, rektor. Mo komm. høgre almenskole, Mo i Rana. (1943).
Hafsten, Ulf, dr. Botanisk Museum, Bergen. (1957).
*Hagemann, Fredrik, statsgeolog. Norges geologiske undersøkelse, Oslo NV. (1951).
*Hagner, A. F., professor. Dept. of Geology, University of Illinois, Urbana, Ill., U.S.A. (1947).
Hamar, Georg, vit.assistent. Institutt for Geologi, Blindern, Oslo. (1958).
Hansen, Kaj, dr. Gammeltoftsgade 16, København K. (1947).
*Harry, W. T., B. Sc. Department of Geology, The University, St. Andrews, Fife, Scotland. (1949).
*Hartley, Jack, B. Sc. Department of Geology, University, Leeds 2, England. (1949).
*Hawkes, Leonard, professor, D. Sc., F.R.S. 26 Moore Lane, Rickmansworth, Herts., England. (1915).
*Heber, Gustav, advokat. Oscarsgt. 49, Oslo. (1937).
*Heber, Gustav, bygningsingeniør. Eikskollen 11, Røa, Oslo. (1942).
*Heier, K. S., univ. stip. Geologisk museum, Oslo NØ. (1952).
*Heintz, Anatol, professor. Geologisk museum, Oslo NØ. (1926).
*Heintz, Natascha, vitensk. assistent. Geologisk museum, Oslo NØ. (1951).
Heltzen, Anders M., bergingeniør. Sulitjelma Gruber, Sulitjelma. (1941).
*Helverschou, Kaare, disponent. Villavegen 9, Frøen, Oslo. (1943).
*Henderson, Donald M., professor. Dept. of Geology, University of Illinois, Urbana, Ill., U.S.A. (1949).
*Henningsmoen, Gunnar, førstekonservator. Geologisk museum, Oslo NØ. (1941).

*Hernes, Ivar, amanuensis. Geologisk institutt. Bergen. (1947).
*Hesse, P. A. Jürgen, bergingenjör. Björkhagsvägen, Ormsta, Vallentuna, Sverige. (1936).
*Hessland, Ivar, professor. Stockholms Högskola, Stockholm. (1947).
Hjelle, Audun, cand. mag. Institutt for Geologi, Blindern, Oslo. (1958).
Hjelmquist, Sven, professor. Geologiska Inst., Lund, Sverige. (1949).
Hofseth, Arne, professor. Norges Tekniske Høgskole, Trondheim. (1952).
Holmberg, Sigurd, amanuens. Van Dürens väg 35 A, Lund, Sverige. (1953).
Holmesland, P. B., overingeniør. Herøya pr. Porsgrunn, (1954).
Holmsen, Bjarne, ingeniør. Charlotte Andersens vei 28, Smestad, Oslo. (1941).
*Holmsen, Gunnar, statsgeolog. Skådalen, Oslo. (1908).
*Holmsen, Per, statsgeolog. Norges geologiske undersøkelse, Oslo NV. (1940).
Holtedahl, Hans, førstekonservator. Geologisk institutt, Bergen. (1948).
*Holtedahl, Olaf, professor. Geologisk institutt, Blindern, Oslo. (1908).
*Howe, Henry, V., professor. School of Geology, Louisiana State University, Baton Rouge, Louisiana, U.S.A. (1953).
Huseby, Fredrik, cand. real. Geologisk institutt, N.T.H., Trondheim. (1951).
*Høeg, Ove Arbo, professor. Farmasøytisk institutt, Blindern, Oslo. (1924).
Høegh-Omdal, S. K., byråsjef. Utgarveien 12, Jar pr. Oslo. (1945).
Ihle, Ole K., stud. real. Norges geologiske undersøkelse, Oslo. NV. (1956).
Ingvaldsen, Karl, dir. Sverresgt. 4, Trondheim. (1956).
*Isachsen, Fridtjov, professor. Geografisk institutt, Blindern, Oslo. (1929).
Iversen, Anker, preparant. Geologisk institutt, N.T.H., Trondheim. (1953).
*Jakhelln, Johanne Hødal, cand. real. United Nations, Box 20, Gr. Central P. O., New York 17, N.Y., U.S.A. (1943).
Jakhelln, Kirsten, fru. Irisvegen 18, Berg, Oslo. (1953).
Jensen, Einar, dr. Villavegen 3, Rjukan. (1939).
Johansen, Erling, stipendiat. Kråkerøy, Fredrikstad. (1953).
Jørstad, Finn, geolog. Norges geotekniske institutt, Blindern. (1957).
*Jøsang, Ottar, mag. scient. Geologisk Institutt, N.T.H., Trondheim. (1956.)
*Kautsky, Gunnar, statsgeolog. Sveriges Geologiska Undersökning, Stockholm 50, Sverige. (1952).
*Kennedy, W. Q., D. Sc., F. R. S., professor. University of Leeds, Leeds 2, England. (1947).
*Kiil, Erling, bergingeniør. Brantenborgveien 2, Slemdal, Oslo. (1922).
*Klompé, Theo, professor. Dept. of Geology, Faculty of Science, Chulalongkorn University, Phya Thai Rd., Bangkok, Thailand. (1947).
Klüver, Emil, ingeniør. Statens toll-laboratorium, Oslo. (1926).
*Kolderup, Niels-Henr., professor, Geologisk institutt, Bergen. (1919).
*Kollerud, Martha, cand. mag. Trondheimsveien 10, Oslo. (1919).
Kraft Johanssen, J., direktør. A/S Sydvaranger, Kongens gt. 5, Oslo. (1955).
*Krauskopf, K. B., professor. Geol. Dept. Stanford University, Stanford, Cal. U.S.A. (1953).
*Kristoffersen, K., dr. A/S Norsk Jernverk, Mo i Rana. (1941).
*Kullerud, Gunnar, dr. Geophysical Laboratory, 2801 Upton Street, Washington 8, D.C., U.S.A. (1948).

*Kulling, Oskar, statsgeolog. Sveriges Geologiska Undersökning. Stockholm 50, Sverige. (1953).

Kvale, Anders, professor. Geologisk institutt, Bergen. (1936).

Kvalheim, Aslak, laboratoriesjef. Statens råstofflaboratorium, Østmarka, Trondheim. (1944).

Landergren, Sture, dr. Sveriges Geologiska Undersökning, Stockholm 50. (1943).

Landmark, Einar, direktør. Tidemandsgt. 14, Oslo. (1941).

Landmark, Kåre, direktør. Tromsø museum, Tromsø. (1943).

*Larssen, Kari Egede, geol. ass. Norges geologiske undersøkelse. Oslo. NV (1956).

*Larsson, Tollef, cand. real. Engene Fabrikker, Sætre i Hurum. (1945).

Laursen, Dan., lektor. Julius vej 6, Gentofte, København. (1947).

*Lien, Håkon, geolog. A/S Sydvaranger gruber, Kirkenes. (1956).

Liestøl, Gerd Brevig, vit. assistent. Institutt for Geologi, Blindern, Oslo. (1958).

Liestøl, Olav, glasiolog, Norsk polarinstitutt, Observatoriegt. 1, Oslo. (1947).

*Lindley, Henry W., dr. Die techn. Hochschule, Wullner Str. 2, Aachen, Tyskland. (1928).

Ljunggren, Pontus, docent. Mineralogisk-Geologiska Institutionen, Lund, Sverige. (1952).

Logn, Ørnulf, lic. techn. Fosdalen Bergverks A/S, Malm. (1953).

Lund, Kjell, direktør. Kvernveien 7, Øvre Ullern — Oslo. (1938).

*Lund, Lars, mag. sc. Forsvarets forskningsinstitutt, Kjeller pr. Lillestrøm. (1943).

Lund, Worm, bergingeniør. A/S Sydvaranger, Kongensgt. 5, Oslo. (1941).

*Lundby, Sven Erik, arkitekt. Norges byggforskningsinstitutt, Blindern, Oslo. (1937).

Løddesøl, Åsulv, direktør. Det norske myrselskap, Rosenkrantzgt. 8, Oslo. (1938).

Løvaas, Gunnar, bergingeniør. Skorovas Gruber, Skorovatn p. å. (1949).

*Låg, J., professor, Norges landbrukshøgskole, Vollebek. (1943).

Mackenzie Scott, Wm. Geophysical Laboratory, 2801 Upton Street, Washington 8, D. C., U.S.A. (1956).

Magnusson, N. H., överdirektör. Vallhallavägen 46, Stockholm. (1937).

*Major, Harald, geolog. Norsk polarinstitutt, Observatoriegt. 1, Oslo. (1944).

Marklund, Nils, fil. lic. Min. geol. Inst., Uppsala 1. (1951).

*Marmo, Vladi, dr. Otakallio B. 14, Otaniemi, Finnland. (1949).

*Marstrander, Henning, bergingeniør. 2924 Leland Road, Homewood, Birmingham 9, Alabama, U.S.A. (1917).

*Marthinussen, Marius, lektor. Ski komm. h. almenskole. Ski. (1931).

*Mason, Brian, dr. The American Mus. of Nat. History, Central Park West at 79th Street. New York 24, N. Y., U.S.A. (1953).

McCulloh, Thane H., M. Sc. Division of Physical Sciences, University of California, Riverside, Cal. U.S.A. (1951).

Mellis, Otto, professor. Min. inst. Stockholms Högskola, Stockholm. (1951).

[1]Michot, Paul, professor. Inst. de Géologie, Université de Liege, Belgia. (1951).

Monsen, Astrid, konservator. Nyhaugsveien 10, Minde pr. Bergen. (1935).

Mortensen, Odd, cand. real. Postboks 744, Bergen. (1938).
Mortenson, Magne, professor. Norges tekniske høgskole, Trondheim. (1948).
Munck, Sole, museumsinspektør. Mineralogisk og Geologisk Museum, Østervoldgade 7, København K. (1948).
Muret, Gerald, 1 rue Colbert, Dakar, A.O.F. (1956).
*Murray, Grover, E., professor. School of Geology, Louisiana State University. Baton Rouge, Louisiana, U.S.A. (1953).
Näykki, Ossi, fil. kand. Pihlajatie 43A, Helsingfors, Finnland. (1956).
*Neumann, H., førstekonservator. Geologisk museum, Oslo NØ. (1940).
Nilssen, Borghild, cand. mag. Geologisk museum, Oslo NØ. (1956).
*Noe-Nygaard, Arne, professor. Østervoldgate 7, København K. (1934).
Norin, Erik, professor. Mineralogisk-geologiska Institution, Uppsala 1. (1947).
*Nosow, Edmund, dr. Box 282, Kentucky Geological Survey, Hopkinsville. Kentucky, U.S.A. (1953).
*Nørregaard, E. M., cand. mag. Mineralogisk og Geologisk Museum, Østervoldgade 7, København K. (1917).
*Oftedahl, Christoffer, statsgeolog. Festningsv. 6 Stabekk. (1941).
*Oftedal, Ivar, professor. Institutt for Geologi, Blindern, Oslo. (1918).
*Orvin, A. K., direktør. Håkon den godes vei 21, Vindern, Oslo. (1913).
Ottesen, P. O., lensmann. Manger pr. Bergen. (1915).
*Padget, Erna, kjemiker. Stallvägen 26, Roslags-Näsby, Sverige. (1955).
*Padget, Peter, dr. Sveriges geologiska undersökning, Stokholm 50, Sverige. (1954).
Paulsen, Nils, bergingeniør. Berg, Maridalen, Oslo. (1947).
Pehkonen, Eero, geolog. Geologiska Forskningsanstalten i Finnland, Boulevardgt. 29, Helsingfors, Finnland. (1955).
*Pettersson, Adam, direktør. Lysaker ved Oslo. (1918).
*Poulsen, Arthur O., statsgeolog. Norges geologiske undersøkelse, Oslo NV. (1941).
*Quensel, Percy, professor. Stockholms Högskola, Stockholm. (1916).
*Ramberg, Hans, professor. Dept. of Geology, Univ. of Chicago, Chicago 37, Ill., U.S.A. (1941).
Ramsli, Gunnar, cand. real. Landbruks dept., Victoria terrasse 3, Oslo. (1948).
*Randall, B.A.O. Department of Geology, Kings College, Newcastle, England. (1958).
Rankama, Kalervo, professor, Geologisk Institut, Universitetet, Helsingfors. (1947).
Rao, S. V. L., ass. lecturer in mineralogy. Indian Institute of Technology, Kharagpur, India. (1956).
Regnéll, Gerhard, professor Geologisk-paleontologiska Inst., Lund, Sverige. (1947).
*Reitan, Paul H., geolog, N.G.U. Geologisk museum, Oslo. NØ. (1956).
*Rosendahl, Halvor, konservator. Geologisk museum, Oslo NØ. (1918).
*Rosenlund, A. L., jernbanegeolog. Drammensveien 103, Oslo. (1912).
Rosenqvist, Ivan Th., professor. Geoteknisk institutt, Blindern, Oslo. (1941).
Ross, Harald N., direktør, Kongsberg sølvverk, Kongsberg. (1947).
*Rønning, O., ingeniør. Konvallvn. 52, Oslo. (1938).

Sahlin, Anders, ingenjør. L. M. E., Stockholm 32, Sverige. (1953).
Samuelsen, Andreas, lektor. Lerkeveien 30, Bergen. (1929).
*Savolahti, Antti, fil. kand. Jääkärinkatu 10A, Helsingfors, Finnland. (1956).
*Scheumann, K. H., professor. Universität Bonn, Königstrasse 67, Bonn a. Rhein, Tyskland. (1928).
Sellevold, M. A., cand. real. Geologisk Institutt, Bergen. (1954).
Selmer-Olsen, Rolf S., amanuensis, Geol. Inst., N.T.H., Trondheim. (1948).
Semb, Gunnar, forsøksleder. Norges landbrukshøgskole, Vollebekk. (1941).
*Siggerud, Thor, statsgeolog. Norges geologiske undersøkelse, Oslo NV. (1951).
Skjerlie, Finn, geolog, Geofysisk Malmleting, Trondheim. (1951).
*Skjeseth, Steinar, statsgeolog, Norges geologiske undersøkelse, Oslo NV. (1949).
Skordal, Asbjørn, geolog. «Vestråt». Elvegaten 18, Trondheim. (1946).
Skålvoll, Harald, cand. mag. Norges geologiske undersøkelse, Oslo NV. (1956).
Smaadal, Gerd Vogt, cand. mag. Halvorsens vei 36, Blommenholm. (1951).
*Sobral, José M., dr. Avenida de los incas 3020, Buenos Aires. (1931).
Soot-Ryen, T., direktør, Tromsø museum, Tromsø. (1946).
*Spjeldnæs, Nils, univ. stip. Institutt for Geologi, Blindern, Oslo. (1946).
*Steinsvoll, Søren, overgartner. Botanisk hage, Trondheimsvn. 23, Oslo NØ. (1942).
Stenvik, Kr., lab.ing. Christian Michelsensgt. 19, Oslo. (1946).
Storebakken, H. C., cand. real., Stockholms Tekniska Högskola, Stockholm 70, Sverige. (1940).
*Strand, Trygve, professor. Institutt for Geologi, Blindern, Oslo. (1927).
*Strøm, Kaare, professor. Limnologisk institutt, Blindern, Oslo. (1932).
*Størmer, Leif, professor. Institutt for Geologi, Blindern, Oslo. (1925).
Sund, Tore, dosent. Norges handelshøyskole, Bergen. (1943).
*Sverdrup, Thor Lorck, statsgeolog. Norges geologiske undersøkelse, Oslo N.V. (1956).
*Sverre, Erik, jr., disponent. Drammensvn. 44b, Oslo. (1946).
Svinndal, Sverre, geolog. A/S Norsk Bergverk, Søve, Ulefoss. (1953).
*Sweet, Walter, dr. Department of Geology, The Ohio State University, Columbus 10, Ohio, U.S.A. (1957).
Sæbø, Per Chr., cand. mag. Geologisk museum, Oslo NØ. (1956).
Sæther, Egil, dr. Harestua. (1943).
*Sørbye, Ruth C., cand. real. Sollien 72D, Bergen. (1941).
*Sørensen, Henning, mag. scient. Mineralogisk Museum, Østervoldgade 7. København K. (1952).
*Thorkildsen, Chr. Dick, cand.mag. Blindern Studenterhjem, Blindern. (1956).
Thorslund, Per, professor. Paleontologiska Institutionen, Uppsala 8. (1940),
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2	korresponderende medlemmer.
126	livsvarige medlemmer.
123	årsbetalende medlemmer.
251	medlemmer.